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TWO INTERESTING NEW FISHES FROM SOUTH AFRICA.*

By J. L. B. SMITH.

(With Plates I and II, and two Text-figures.)

(Read September 18, 1935.)

Family SCYMNORHINIDAE.

Regan (Ann. Mag. Nat. Hist., 1908 (8), vol. ii, p. 40) defined the family SQUALIDAE so widely as to include even genera such as *Pristiophorus* M & H, which are to-day generally accorded full family rank. *Scymnorhinus* Bonap. and *Echinorhinus* Blnv., and their relatives, without fin-spines, appear to merit family distinction from the SQUALIDAE. Actually certain authorities favour even recognition of the families ECHINORHINIDAE and SCYMNORHINIDAE as distinct one from the other. Although this appears to set rather narrow limits for family distinction, it is accepted here.

Scymnorhinus Bonap. replaces *Scymnus* Cuv., preoccupied (Kugelman 1814, a genus of Beetles). These two genera are sometimes accepted as synonyms of *Dalatias* Raf. (1810), but according to Jordan and Evermann (The Genera of Fishes, 1917, p. 97) this is not established, and is not accepted here.

Scymnorhinus has not previously been recorded from South Africa. A new species of that genus is described below.

Scymnorhinus brevipinnis n. sp.

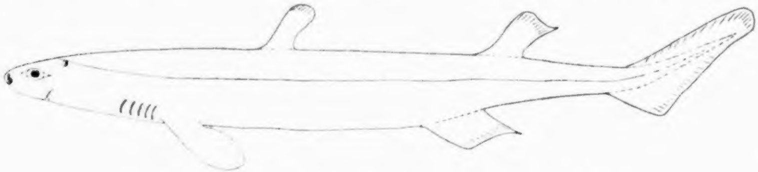
No anal fin, no fin-spines, no nictitating membrane.

Greatest depth of body 9–10 in total length. First gill-slit about midway between tip of snout and origin of first dorsal. Longitudinal diameter of orbit 7·5–8·5, vertical diameter 19–22, prespiracular distance 4·5, preoral length 6·2–6·4, width of mouth 6·0–6·3 in distance from tip of snout to origin of first dorsal. Inner internasal distance 1·8 in preoral length. Interspiracular distance 1·5 in prespiracular length.

Mouth transverse, lower lip thick, no labial folds. A straight longitudinal groove from each corner of mouth. 19 compressed triangular teeth in lower jaw. The central (anterior) tooth erect, the remainder oblique,

* The Council desires to acknowledge the receipt of a grant from the Carnegie Corporation through the Research Grant Board towards the cost of printing this paper.

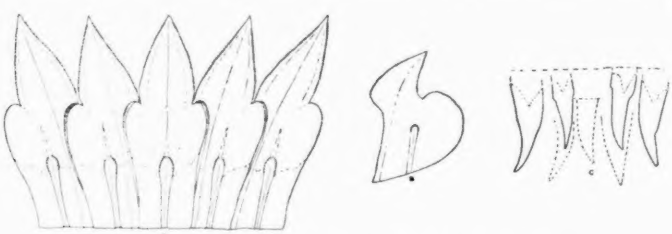
increasingly so posteriorly. Edges serrate, 19–26 fine serrae on each edge (fig. 2). Behind the single row of functioning teeth are four overlapping rows of inwardly depressed teeth in succession. 19 series of teeth in upper jaw, narrow and pointed: central tooth almost vertical, remainder oblique,



TEXT-FIG. 1.—*Scymnorhinus brevipinnis* n. sp. (type). (× ¼.)

edges entire. The second row close behind the first, and behind these three more rows in succession.

First dorsal inserted midway between origin of second dorsal and hind margin of eye, 2·2–2·3 times nearer origin of pectorals than origin of second dorsal, 1·7 times than origin of ventrals, and twice as far from hind margin of caudal as from snout tip. Second dorsal 1·2 times further from hind



TEXT-FIG. 2.—Dentition of *Scymnorhinus brevipinnis* n. sp.
A. Anterior teeth of lower jaw. B. Posterior tooth of same.
C. Anterior teeth of upper jaw; those in second row with interrupted outline.
(All × 2·3.)

margin of caudal than from origin of first dorsal. Three-quarters of ventral base in advance of second dorsal. First dorsal about as long as second, slightly less than prespiracular length. Base of first dorsal 1·5, base of second dorsal 1·2 in length of first dorsal. Length of ventrals 1·3 in, base of ventrals 1·3 times, length of first dorsal. Pectorals 1·3–1·4 times length of first dorsal.

Depth of gill-openings about equal to longitudinal diameter of eye. Nostrils more or less rounded, separated, no cirri or oronasal grooves. A slight depression in lower surface of snout between nostrils. Spiracles large.

Caudal lobes small: greatest transaxial width of caudal fin scarcely greater than prespiracular length.

The whole body and head covered with small scales, each more or less quadrate, having a dorsal ridge terminating in a stout spine, usually also one or two minute basal spines.

Colour.—Uniform dark brown, slightly lighter below. Tips of fins slightly lighter.

Length.—770–1100 mm.

Holotype in the Albany Museum.

Three specimens examined.

These interesting fishes were taken by the trawler "Algoa Bay" at a depth of 110–150 fathoms, some 35 miles south of Cape Recife, about 34° 32′ S., 25° 42′ E., and were presented by Mr. H. D. Jackson, manager of Messrs. Irvin & Johnson at Port Elizabeth, who has also previously donated valuable specimens.

S. brevipinnis is very closely related to the only other species of the genus that has yet been described, *licha* Bonn., which has been recorded from the western North Atlantic and the Mediterranean, from fairly deep water. Descriptions of that species available to me are exceedingly meagre, the only figure seen being that of Goode and Bean (Ocean. Ichthy., 1895, p. 7, fig. 4,* *Scymnorhinus lichia*). *S. brevipinnis* appears to differ from *licha* in numerous dimensional relationships, notably in the smaller fins, the caudal lobes being markedly lower. Also Günther (Cat. Fish. B.M., 1861, vol. viii, p. 426), and others, have stated that the teeth of the lower jaw in *licha* are oblique in juveniles but erect in adults. In my specimens of *brevipinnis*, of which the larger are presumably adults, all but the central symphysial erect tooth of the lower jaw are oblique, the posterior teeth very markedly so.

In any case, since a number of South African species of fishes, until recently held to be identical with those from the northern hemisphere, have upon detailed comparison of suitable material proved to be distinct, it is felt expedient to maintain *brevipinnis* as distinct from *licha* until such time as equivalent material from all the recorded areas may be compared.

Jordan and Fowler (Proc. U.S. Nat. Mus., 1903, vol. xxvi, p. 63, *Dalatias licha*) have given a very brief account of a stuffed specimen of *Scymnorhinus* from Japan, which they have diagnosed as identical with the Atlantic species. This has been accepted by Regan (*loc. cit.*). The few details given by Jordan and Fowler agree neither with my specimens nor with descriptions and the figure of *licha*. It was stated, for example, that in the Japanese specimen the anterior margin of the mouth is before the anterior border of the eye.

* The text gives fig. 3.

Although these fishes are bathybial, and so with little to hinder wide distribution, they are obviously very sluggish in habit, and it is not unlikely that a re-examination of the specimen from Japan will establish that it is a distinct species.

Family Trichonotidae.

No member of this family has previously been recorded from South Africa. Records have hitherto been from the Indo-Australian area.

A new species of the genus *Taeniolabrus* Stndnr. from South Africa is now described.

Taeniolabrus marleyi n. sp.

(Plates I and II.)

Body very elongate, sub-quadrangular in cross-section, somewhat deeper than wide.

Depth 12, length of head (tip snout) 5, or (tip lower jaw) 4·7, in length of body. Eye 6, snout 3·2, postorbital part of head 1·7 in length of head (tip snout).

Head little depressed, snout very sharp, dorsal profile even. Eyes prominent, sub-dorsal in position, projecting above the profile, but vision chiefly lateral. Over the upper margin of the pupil is a small extension from the iris which divides below into radiating stripes, all of a golden colour. Anterior adipose eyelid moderately developed. Interorbital very narrow, with a small longitudinal ridge. Nostrils paired, rounded, minute. Lower margin of preorbital slightly concave above maxilla. Several pores and canals on preorbital and snout. Preorbital depth somewhat less than longitudinal diameter of orbit. Suboperele and interopercle much enlarged, covering branchiostegals.

Gill-opening large, membranes free from isthmus, unite beneath the hind edge of maxilla. Branchiostegals 5. Pseudobranchiae present. Gill-rakers 3 + 21, very fine and slender, 1·3 in gill-filaments which are 2 in eye.

Vent normal, in front of anal origin.

Mouth large, almost horizontal, slightly protractile. Maxilla partly concealed beneath preorbital, extends to below middle of orbit. The lower jaw projects strongly, forming a prominent mental lobe or chin, the upper jaw almost included. Lower lips finely papillose. Minute curved villiform teeth in a narrow band in each jaw. Upper jaw with a large dentate symphysial knob, teeth recurved, slightly enlarged. Minute teeth on vomer in an angular patch with anterior median projection. Similar small teeth in a narrow band on palatines. Tongue edentate, apically dilated, free.

The intestinal tract is simple, being merely siphonal, the stomach elongate: no pyloric caeca. Liver bilobed, the lobes even, extending almost above vent. The presence of a gall-bladder cannot be established. No air-bladder.

D 47 (or III 44) originates slightly behind the base of the pectoral. Anterior three rays filamentous, spiniform. First two rays detached from remainder, first 2·0, second 1·8 times head. Third ray 1·5 times head. The fourth ray is 2 in head and simple but articulated. The remainder are mostly branched, often very indistinctly so. From the fourth, the rays increase in length slightly to the 10th and are thereafter subequal.

A 39 (or I 38, the fig., Pl. I, shows 37 in error) originates below the 10th dorsal ray, less than a head length behind head, below the tip of the pectoral. 1st ray spiniform, short: remainder bifurcated or branched. Rays gradually increase posteriorly to almost length of dorsal rays.

Pectorals 1·4 in head, inserted fairly low, of 12 branched rays; tip reaches to 14th lateral scale, above origin of anal.

Ventrals I, 5, inserted close together, in advance of pectorals. Spine weak: inner ray simple, remainder branched. 1st ray shortest, remainder increase to 4th, which is filamentous, the total length being 1·4 times the head, the filament is as long again as the fin, which reaches the origin of the anal.

Caudal broadly hastate, of 13 branched rays, slightly longer than head.

Scales cycloid, longer than wide, with angular hind margin, the edges meeting at an angle of about 80° (Pl. II). Lateral line scales with a deep notch in hind edge, and a short vertical groove above the tube (Pl. II). Lateral line straight, tubules simple. l.l. 57, l.tr. $\frac{4\frac{1}{2}}{5\frac{1}{2}}$, 10 predorsal scales, end above hind margin of preopercle. Head naked except for five scales below the orbit down hind margin of preorbital and 3–4 more behind angle of mouth along anterior margin of preopercle.

Colour (Alive): "Above amber, studded with turquoise blue and red dots. The lower surface faint rosy. Anals and ventrals with numerous dark red dots. Eye with about twenty golden lines, umbrous red above."

(Preserved): Light yellow-brown above with 11 faint darker cross-bars, wider than eye, not reaching to ventral surface, the first over nape extending on to opercle, the last below the last dorsal rays. Series of dusky bordered ocelli along the body, 6 series anteriorly, becoming fewer posteriorly: one ocellus on each lateral line scale. Similar ocelli in about three series along side of head. A few dark dots along lower surface of body. Dorsal faint dusky with 6–8 series of ocelli, anterior two spines with alternate light and dark annular rings. Irregular dark spots, larger posteriorly, over fin. Caudal similar. Anal similar, but lighter, and fewer ocelli. Pectorals light. Ventrals with signs of darker markings. A few dusky mottlings on nape and muzzle. Iris, iridal flap, and radiating lines golden.

Length.—190 mm.

Locality.—Durban (6th June 1935).

Type in the Albany Museum. (H. W. B. M. 969).

This interesting specimen was presented by Mr. H. W. Bell Marley, Principal Fisheries Officer of Natal, after whom it is named. His colour notes of the live fish are given above. Mr. Bell Marley has also sent another specimen which, while almost certainly conspecific, nevertheless differs markedly in the nature and development of the fins. This smaller specimen (155 mm. total length) has D 45, A 37 and l.l. 55. The first three dorsal rays are only slightly longer than the remainder, the third being actually the longest, about 1·7 in head, while the remaining rays are relatively shorter than those of the type, and are almost all simple. Further, the dorsal originates about an eye diameter behind the pectoral base. The caudal is only $\frac{2}{3}$ as long as the head, and broadly rounded. The anal is similar to that of the type, but the rays are shorter, and the origin of the fin is almost a head length behind the head, well behind the pectoral tip. The 4th ventral ray is only slightly extended, the total length being 1·4 in head, and even the filamentous tip does not reach near the vent. There are 3 + 19 gill-rakers, and the vomerine angular patch has no anterior extension. It is difficult to decide whether these two specimens are conspecific or not. The nature of the dorsal and caudal fins alone might justify distinction, but in general features, shape, markings, etc. there is such marked similarity that specific distinction for the smaller specimen would appear venturesome. Neither specimen shows any trace of sexual development, so that immaturity may be the cause of the numerous variations.

Very few species in this family have been described, and very little is known about them. It would certainly appear that a revision of the genera and species is necessary.

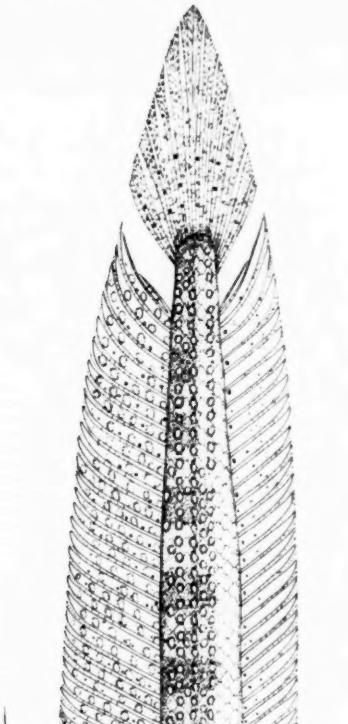
T. marleyi appears to be well differentiated from all others by having the anterior three dorsal rays and the 4th ventral ray elongated, as well as by the scales on the cheek, and by the number of scales in transverse series.

The Ammodytid-like body and head would appear to indicate a mode of existence resembling that of those fishes.

This is a noteworthy addition to the ichthy-fauna list of South Africa.

I wish to express my gratitude to the Research Grant Board of South Africa (Carnegie Fund) for generous financial assistance.

ALBANY MUSEUM,
GRAHAMSTOWN,
August 1935.



Taeniolabrus marleyi n. sp. Nat. size. (Type.)

J. L. B. Smith, del. Neill & Co., Ltd.

Scales of *Taeniolabrus marleyi* n. sp.

Left.—24th lateral line scale, × 21. Arrow indicates dorsal groove adjacent to the tubule.
Right.—24th scale above lateral line, × 23.
Both from right side of type.

J. L. B. Smith. Neill & Co., Ltd.

STUDIES IN DECIDUOUS FRUIT.

III.—The Chemical Changes in Kelsey and Gaviota Plums during Growth.

By I. Donen.

(With six Figures in the Text.)

(Read September 18, 1935.)

Introduction.

The ultimate criterion of successful cultivation of fruit for export is the condition of the fruit, as measured by the accepted standards of good flavour and appearance, when delivered to the customer on the overseas market. The conditions contributing towards good keeping quality are usually divided into cold storage and orchard factors. The importance of proper cold storage treatment has been fully recognised, but attempts to cope with such cold storage problems as internal browning, "leatheriness," internal breakdown, and satisfactory post-storage ripening of plums inevitably point to the fundamental importance of orchard factors (8, 9, 14). These would include meteorological effects, tree characters, and cultural methods.

The published researches dealing with this subject indicate that nutritional and orchard factors greatly affect the performance of fruit trees and the resulting fruit quality (45, 7). The complexity of the problem is so great, however, that as yet no conclusions of a general nature applicable to all orchards and all fruits can be drawn. To establish the best conditions under which fruit can be grown and exported from any particular area of production, tests must be carried out for each different variety of fruit, proper allowances being made for the peculiarities, such as soil and climate, of the particular area. This point has been stressed in the Report of the Food Investigation Board of Great Britain for 1933, where it is pointed out that "the results of trials on fruit carried out with English varieties grown under English conditions are not applicable to varieties grown under conditions which are generally different to a significant degree."

The investigation described in this paper deals with the chemical changes during growth in two varieties of plums, Kelsey and Gaviota, over a period

of two growth seasons, 1933–34 and 1934–35.* The chemical history of the plums has been traced from "petal fall" until cessation of growth on the tree, and it has been attempted to relate these changes to those that take place in the fruit on storage (16). Effects of seasonal and orchard variations have also been observed.

The discussion falls into two parts. In Part I the materials and methods used are described. In Part II the course of chemical change is discussed.

Part I.—Materials and Methods.

Orchard Characters.—Both soil and climatic conditions vary to a remarkable degree from farm to farm in the Winter Rainfall Area of the Cape. In order to determine the significance of these variations on the rate of growth and final chemical composition of the fruit, the samples of plums used in this investigation were taken from orchards on three different farms. Particulars as to locality, soil characters, and management are given below.

Farm A :

Locality.—Somerset West, Cape. Farm situated very near the sea. Altitude 119 feet. Farm is typical because of its high mean temperature during June–July. Rainfall: 25·76 inches per annum (33).

Particulars of Trees.—Gaviota and Kelsey plums worked on Mariana root stock. Trees about ten years old. Kelsey trees showing very good growth. Gaviota trees susceptible to delayed foliation, and in 1934–35 bore no crop.

Soil Characters.—Parent material: probably Malmesbury Shales, possibly old Cape Granite. Soil derived from Malmesbury Shales, Cape Granite, and Table Mountain Sandstone. Depth of soil varies but is never less than 3 feet. Greyish brown. C/N ratio about 13/1 (30). pH about 6·2. Drainage good. Irrigated regularly. Water supply medium.

Management.—Management and cultivation very good. Winter cover crops of peas since 1933. Previous attempts at growth of leguminous cover crop not successful. Regular manuring with P K N. Fertiliser treatment given is comparatively high: 900 lb. P K per acre in 1933–34 season; 600 lb. P K per acre in 1934–35 season. Nitrogen kept at about 30 p.p.m. from August to December and at 20–12 p.p.m. from January to March.

Farm B :

Locality.—Dwaarsrivier Hoek, Banhoek, Cape. Farm situated at the foot of a mountain. Altitude approximately 1100 feet. Rainfall: 48·06 inches per annum (1911–34). Low mean temperature in winter.

Particulars of Trees.—Kelsey trees worked on peach stock. About twenty years old. The trees are well grown, but at one end of the orchard

* These seasons will be referred to in the text as the "first" season and the "second" season respectively.

are periodically almost denuded of both foliage and crop by fierce south-easterly winds.

Gaviota trees are worked on plum stock and are about twenty years old. Well grown and carry good crop.

Soil Characters.—Parent material: Cape Granite intrusive into Malmesbury Shales. Soils: river gravels and sand derived mainly from Cape Granite and partly from Table Mountain Sandstone. Soil medium brown up to 1 foot. pH about 6·8. Fairly well differentiated from subsoil, which is yellowish brown (1 foot to 3 feet), and with pH 5·6. C/N ratio of soil 15/1.

Management.—Management and cultivation good. Generous liming and fertiliser treatment (P K N) for the past twenty years.

Farm C :

Locality.—Elgin, Cape. Situated on a mountain plateau about 900 feet above sea-level. Typical for its cold winters. Rainfall: 41·9 inches per annum (33).

Particulars of Trees.—Kelsey trees worked on peach stock. Trees about six to seven years old. Growth is patchy, from stunted to fairly good. Little leaf prominent. Gaviota trees show good growth and carry good crop.

Soil Characters.—Parent material: Bokkeveld Shales. Superficial deposit only about 10 inches deep. Soil poorly weathered, pebbly. Subsoil consists mainly of gravel. Lower levels consist of clay from Bokkeveld Shales. C/N ratio about 17/1. pH of soil about 6·5. Abundant water supply but drainage free to excessive.

Management.—Management good. Manures applied regularly. Application consists of 200 lb. potassium chloride and 150 lb. superphosphate per acre. Annual clover and barley are sown but crop is usually poor.

There is thus a lack of uniformity as regards age of trees and stock on which they are grown. In the absence of knowledge as to the precise importance and effects of age and stock any differences noted in the plums from orchard to orchard cannot be strictly interpreted. On the other hand, it can be argued that any characteristics of the fruit found to be common to all orchards are capable of general interpretation.

Choice of Sample.—Collection of samples for analysis began about three weeks after the setting of the plums, and continued at weekly intervals until all commercial pickings for export were over. In the 1934–35 season samples of Gaviota plums were collected from orchard C until the fruit was fully ripe and the plums began to drop off the tree. On account of crop failures no Gaviota plums could be collected during that season from either orchards A or B. In all orchards, and during both seasons, it was found impossible to allow Kelsey plums to ripen fully on the tree as they all developed an acute form of "Kelsey Spot." The effect of this malady is usually seen on the flushed portion of the fruit, which becomes soft and watery.

The importance of collecting fruits at the same stage of physiological development for each sample was fully realised. But the only criterion that could be used for obtaining a uniform sample was size. In order to eliminate individual variations from tree to tree the samples were picked from about twenty similar trees in each orchard.

The number of plums per sample was never less than twenty. In the early stages a considerably greater number of fruits had to be used. Haynes and Archbold (25) have found that for apples twenty fruits per sample is adequate to reduce the scatter due to individual variation when the course of chemical changes is being traced. They state that at least thirty fruits are necessary if analyses are being made with the object of comparing differences directly. The assumption that these conclusions should hold for plums also is a reasonable one. A number of analyses were made to determine the significant differences between estimations of similar samples, as errors in sampling are undoubtedly the limiting factor in the accuracy of all the quantitative estimations carried out in the course of this investigation. These errors and those due to methods of analysis will be considered later.

Preparation of Sample for Analysis.—Analysis of the plums was usually commenced within a few hours of picking. Twenty or more uniform fruits were weighed and the average weight per plum determined. The stones were then removed, all adhering flesh being scraped off and weighed. (In calculating the results in amounts per fruit allowance was made for weight of the stone.) The plums were then quartered and divided into two portions. Two alternate quarters of each plum were placed in each lot. One lot was finely cut up by hand and thoroughly mixed. Samples were taken for dry-weight determination and for alcohol extraction.

The second lot was squeezed out in a press and the juice centrifuged. Towards the end of the season and for samples from cold store this procedure for obtaining juice was somewhat modified. As the fruits were very ripe and rather juicy the quartered plums were put through a mincing machine capable of separating most of the residue in an almost dry condition. The juicy pulp was then thoroughly mixed and filtered through a large fluted filter. The juice so obtained was clearer than that obtained by centrifuging and the procedure was quicker.

Methods of Analysis.—The quantities estimated consisted of the following: dry weight, alcohol insoluble residue, specific gravity of juice, acidity, sugars (total and reducing) and total nitrogen.

Dry-weight Determination.—The method used was the same as outlined by Archbold (2, 3). About 80 grams of pulp were weighed out in an open Petri dish and placed in an oven at 50° C. at atmospheric pressure. It was found that the pulp continued to lose weight indefinitely in an oven, but

after eighty hours the loss was almost negligible. The time of drying the pulp in the oven used was therefore standardised at eighty hours. The method gave very good duplications, and the maximum deviation from the mean of duplicate estimations of over twenty samples selected at random was found to be not more than 0·033 per cent. while average deviation was only 0·024 per cent.

Alcohol Insoluble Residue.—About 80 grams of pulp were used for this determination. The method followed was as outlined by Archbold (2, 5). During the early stages of growth, when the fruit was firm, duplications showed a maximum deviation of 1·6 per cent. from the mean. Later in the season, when the fruit softened rapidly, the accuracy of this determination diminished, and the deviation from the mean value of duplicate determinations was about 2·5 per cent.

Acidity.—Acidity was determined on aliquot portions of juice or on alcohol extracts of pulp. By diluting the aliquots to 300 c.c. and using about five drops of phenolphthalein quite a sharp end point was usually obtained. The colouring matter in the alcohol extract masked the end point of the titration to a certain degree, and on this account the acidity determination on the juice seems to be more reliable.

Acidity as determined on juice was calculated back to acidity on fresh weight basis by the formula

$$A = \frac{C(100 - R)}{S} \text{c.c. } N/1,$$

where A = Acidity in c.c. normal acid per 100 grams fresh weight,
C = Acidity in c.c. normal acid per 100 c.c. juice,
R = Alcohol insoluble residue per 100 grams fresh weight,
S = Specific gravity of juice.

The validity of this formula for apple juice has been shown by Haynes (24). That it holds for plum juice also can be seen from Table I. The results were selected at random. In the third column of this table the deviation from the mean value obtained by these methods is shown. This deviation is of the same order as the deviation from mean of duplicate determinations by either method.

Total Nitrogen.—Total nitrogen estimation was carried out on a 2–3 gram sample of dried pulp from the dry-weight determination. The method used for digestion was the standard Kjeldhal ($CuSO_4$ as catalyst) modified to include nitrates.

The estimation was usually run in triplicate. Blank determinations were made and the necessary correction in the titration introduced. It was found that the manipulative error most difficult to eliminate in the macro-method was the almost unavoidable carrying over of traces of alkali

from the distilling flask into the standard acid. In the second season the distillation method was therefore changed to that used in the micro-Kjeldhal. After digesting the pulp in an ordinary Kjeldhal the clear solution was made up to volume and aliquots were used for determination of ammonia. The aliquots were chosen to be equivalent to 2–3 mgms. of nitrogen. N/50 hydrochloric acid and N/75 sodium hydroxide were used, methyl red being the indicator. This method not only saved much time and material but also reduced the manipulative error to zero.

TABLE I.

Acidity in c.c. N/1 per 100 grams fresh weight.		% deviation from the mean.
On juice.	On alcohol extract.	
21·40	21·70	−0·6
21·50	21·60	−0·2
19·40	19·35	0·1
21·40	21·40	0·0
19·90	20·60	−1·7
3·36	3·26	1·5
3·32	3·31	0·2
2·92	2·87	0·9

When investigating the nitrogen content of apples, Archbold (1) found that inefficient mixing of the sample could account for as much as 4–12 per cent. variation in the result, and suggested grinding of the dried tissue to reduce this error. A series of analyses on plums showed that, using the standard macro-method, a variation of 0·75 per cent. from the mean could be obtained on finely ground material and a maximum variation of 2·1 per cent. on the coarse but well-mixed sample. The procedure finally adopted was to pound the sample in a mortar to a coarse powder and then to mix well. Using the micro-distillation technique, an average variation of only 0·5 per cent. from the mean could then be obtained on duplication.

Sugar Analysis.—Considerable difficulties were encountered in the estimation of sugars, especially those obtained by alcoholic extraction from very young fruit. The methods employed were similar to those used by Haynes and Archbold in their work on apples (4, 5, 24, 25), but it was found necessary to introduce certain modifications.

Sugars were estimated either in the alcohol extract of the pulp or in juice. About 100 grams of fresh fruit pulp were used for extraction with alcohol (5). For estimation in juice 20 c.c. of juice were used. The

clearing agents employed were basic lead acetate and sodium hydrogen phosphate.

Total reducing sugars were estimated in the cleared filtrate by the copper reduction method of Lane and Eynon (32). Sucrose was determined by the difference of the copper-reducing values obtained for aliquots of the cleared filtrate before and after inversion of the sugars. Inversion of sucrose was carried out by means of hydrochloric acid (2 per cent. solution). The sugar solution may be allowed to stand with hydrochloric acid at ordinary room temperature for about five days, or the mixture may be heated for twelve minutes in a water-bath at 70° C. (26).

Fructose and glucose were determined by calculation from the copper-reducing value and iodine value of the original cleared filtrate (48). For the iodimetric estimation the solution was decolorised with charcoal (ordinary blood charcoal or special charcoal used for decolorising wines was found to be equally efficacious). Since the writer found that the fructose/glucose ratio in plum sugar extracts is very nearly unity, the fructose factor used in the iodimetric estimation was taken from the values given by Archbold and Widdowson (48) as 0·014 gram iodine per gram of fructose. The tables of Lane and Eynon furthermore gave good agreement between total reducing sugars and the sum of fructose and glucose. Total sugar was obtained as the sum of sucrose and reducing sugars.

Determination of Small Quantities of Sugar.—In the early stages of growth the fruit extracts were highly coloured and contained only small quantities of sugars. At first the method suggested by Widdowson (47) was used for sugar determination. It consists of a determination of the iodine and ferricyanide values (23) of the non-inverted and inverted solutions. The separate sugar fractions were then found by calculation. One modification was introduced: the constants used for the ferricyanide value were taken not from Widdowson's paper but from that of Hulme and Narain (29), who further modified Hanes's ferricyanide method. The accuracy of these constants and of the formula given by the above authors was confirmed by the writer, who determined the glucose, fructose, and invert sugar values for ferricyanide on pure sugars previously carefully dried *in vacuo* over phosphorus pentoxide.

The ferricyanide method has two distinct drawbacks. Firstly, it is rather long. This is a great disadvantage when a number of samples must be analysed simultaneously. Secondly, the results obtained for sucrose by this method are too low. The highly coloured solutions needed four or five boilings with charcoal before a colourless extract could be obtained. The writer found that sucrose is apparently adsorbed by the charcoal, as the copper-reducing values estimated on decolorised extracts

always gave low values for sucrose compared with those obtained on similar solutions which had not been thus decolorised.

The method of Lane and Eynon was therefore adapted for estimations of small quantities of sugar. Special tables were constructed for quantities of sugar ranging from 75 to 30 mgms. of sugar per 100 c.c. of solution. The sugars used for the purpose were all of AR quality, and were previously dried *in vacuo* over phosphorus pentoxide for a period of over four months. The strengths of the Fehling's solutions used were one-fifth of those used by Lane and Eynon. The tables were constructed for fructose, dextrose, and invert sugars only, and the titration was carried out in exactly the same manner as described by Lane and Eynon. The method was employed in conjunction with the iodine determination, and the results obtained compared favourably with those obtained by the use of the ordinary Fehling's method.

It was found, however, that it was essential to decolorise the solution with charcoal, as the colouring matter interfered with the copper estimation and gave high values for reducing sugars. That the high values obtained were due to the colouring matter only was concluded from the following observations:—

(*a*) The reducing sugars estimated on decolorised solutions were in excellent agreement with those obtained from estimations on juice (juice gives a colourless solution on clearing), whilst the highly coloured solutions gave widely different and obviously contradictory results.

(*b*) The Fehling value of a coloured solution fell steadily with successive boilings with charcoal until the solution became colourless and the value then remained steady.

(*c*) With ripening of the plums the alcohol extracts showed decreasing amounts of colouring matter. It was then found that the Fehling values estimated on decolorised and non-decolorised solutions were very nearly the same.

Since sucrose is estimated by the difference between the Fehling values of inverted and non-inverted solutions, it is obvious that no error is introduced if the estimations are carried out on non-decolorised solutions. In extreme cases, when the sugar solution was highly coloured, it was essential to boil the sugar solution once with charcoal in order to obtain a sharp end point in the Fehling titration. A single boiling in such cases did not affect the sucrose value appreciably.

Comparison of Sugars estimated on Alcoholic Extracts and on the Expressed Juice.—Archbold and Haynes (25) have shown that there is good agreement between sugar content of apples as determined on alcohol extracts and as

calculated from expressed juice. Emmett (18) has confirmed this for pears. A series of duplicate determinations on plum material showed that this also holds for the total sugar content of plums (Table II).

TABLE II.

SHOWING COMPARISON OF THE SUGAR CONTENT OF SAMPLES OF KELSEY PLUMS ESTIMATED ON JUICE AND ON ALCOHOLIC EXTRACTS.

Results in grams per 100 grams Fresh weight.

Sample.	Dextrose.		Fructose.		Red-sugar.		Sucrose.		Total.	
	A.E.	Juice.	A.E.	Juice.	A.E.	Juice.	A.E.	Juice.	A.E.	Juice.
1	2·64	2·50	2·60	2·42	5·24	4·92	6·98	7·31	12·22	12·23
2	2·39	2·41	2·56	2·62	4·95	5·03	6·81	6·74	11·76	11·77
3	2·60	2·48	3·05	2·97	5·65	5·45	6·31	6·65	11·96	12·10
4	2·34	2·22	2·83	2·64	5·17	4·86	7·16	7·58	12·33	12·44
5	2·80	2·55	3·63	3·52	6·42	6·07	4·33	4·90	10·75	10·97
6	2·54	2·38	2·90	2·73	5·44	5·11	7·30	7·49	12·74	12·60
7	..	..	..	..	5·25	5·18	7·64	7·75	12·89	12·93
8	..	..	..	..	5·95	5·73	4·82	5·04	10·77	10·77
9	2·64	2·32	2·24	2·25	4·88	4·57	0·48	0·78	5·35	5·36
10	2·81	2·44	2·23	2·23	5·04	4·67	0·76	1·23	5·80	5·90
11	3·08	2·56	2·12	2·14	5·20	4·70	2·06	2·70	7·26	7·40
12	..	..	..	..	3·44	3·35	0·27	0·30	3·71	3·65

It will be observed that a significant difference exists between reducing sugars as determined in alcohol extracts and on expressed juice. Reducing sugars when determined in the pulp are in most cases higher than the sugars determined in the juice, while the sucrose content is consistently lower. The excellent agreement between total sugars as determined by the two methods definitely indicates that the observed differences in reducing sugars and sucrose content are due to inversion of sucrose in the alcohol extracts during the estimation. This was especially noticeable during the early stages when the acid content of the fruit was high, and occasional samples showed as much as 50 per cent. difference in sucrose content. This experience is somewhat at variance with that of Archbold, who states that no hydrolysis of sucrose took place during alcoholic extraction (5). This author found, furthermore, that calcium carbonate or ammonia only partially neutralised the acid in alcoholic solution, and that addition of calcium carbonate to the receiving flask of the Soxhlet apparatus did not

affect the result. This observation was also made by the author of this paper, and it would seem, therefore, that the hydrolysis must take place during the preliminary soaking of the pulp in alcohol. This was proved in the following way. A sample of pulp was covered with alcohol and put on ice. After three hours the alcohol was decanted and fresh alcohol substituted. The alcohol extract was immediately distilled *in vacuo* at 20°–25° C. The residual liquid was diluted with water, neutralised, and put back on the ice. The pulp was treated in this way four times and it was finally extracted in a Soxhlet in the usual way and the sugars estimated. The results obtained for sucrose and total sugar in the alcohol extract were in good agreement with those obtained from a determination in juice. Yet a similar sample of pulp which was allowed to soak in alcohol at room temperature showed about 20 per cent. inversion of sucrose.

Accuracy and Limits of Error.—In order to interpret significant differences in the chemical composition of comparative samples of plums, a number of duplicate analyses were made in the same sample and in a number of separate samples of plums at the same stage of maturity. The results of twenty-two estimations are given in Table III, which shows the average percentage deviations from the mean of duplicates.

TABLE III.

Nature of estimation.	Average mean deviation on duplicate estimations.	Average mean deviation on duplicate samples (M.D.).	Significant differences (2 M.D.).
	Per cent.	Per cent.	Per cent.
Dextrose . . .	0·70	1·51	3·02
Fructose . . .	1·03	2·57	5·14
Reducing sugars . .	0·57	1·78	3·56
Sucrose . . .	1·76	2·68	5·36
Total sugar	0·95	0·73	1·90
Dry weight . . .	0·033	1·71	3·42
Alcohol insoluble residue	1·50	1·88	3·76
Acidity . . .	1·70	4·33	8·66
Nitrogen . . .	0·75	2·46	4·92

The fructose and sucrose estimations carry the errors due to the estimations of reducing sugars and glucose, and reducing sugars and total sugars respectively. Their relative error is consequently high. The rather high error in the acidity estimation is due to the difficulty of obtaining the exact end point of the titration.

The third column in Table III gives the overall error, as it includes both the sampling error and error due to methods of estimation. The significance of differences in the analyses has been obtained by doubling the computed error and is shown in the last column of the table.

Part II.—The Course of Chemical Change during Growth.

The results of the analyses of the plums during growth in the two seasons, 1933–34 and 1934–35, are given in Tables IV–X. The tables show the changes in concentration during growth. The amounts per fruit and the rates of change in the constituents with time were calculated from these tables.

Table IV.

Analyses of Kelsey Plums during Growth. Oct. 1934 to Feb. 1935. Orchard A.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 8th Oct.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Starch.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.		A.
8.10.34	0	600	0·71	13·60	0·985	0·825	1·810	0·316	2·126	6·17	0·382	None	20·2
13.10.34	5	335	1·77	12·49	1·081	0·709	1·79	..	..	5·17	0·273	,,	22·0
18.10.34	10	150	4·41	13·08	1·37	0·77	2·14	0·16	2·30	5·05	0·254	Very slight	23·0
25.10.34	17	100	6·63	12·56	1·32	0·95	2·27	..	..	4·83	0·210	Slight	23·2
1.11.34	24	55	12·64	12·22	1·59	0·95	2·54	0·25	2·79	4·82	0·169	Much	22·8
8.11.34	31	40	16·65	12·20	1·79	0·95	2·74	..	..	4·51	0·156	Very slight	22·9
15.11.34	38	30	22·50	11·36	1·64	1·05	2·69	0·16	2·85	4·26	0·157	None	21·1
22.11.34	45	30	24·9	10·86	1·73	1·06	2·80	0·05	2·85	4·02	0·150	,,	18·8
28.11.34	51	20	31·7	10·84	1·90	1·40	3·30	0·14	3·44	3·75	0·142	,,	20·0
5.12.34	58	20	44·8	10·23	2·18	1·43	3·62	0·23	3·85	3·30	0·128	,,	20·6
12.12.34	65	20	55·2	10·26	2·27	1·61	3·88	0·31	4·19	3·06	0·123	,,	19·4
20.12.34	73	20	64·1	11·03	2·32	2·25	4·57	0·78	5·35	2·73	0·117	,,	21·4
27.12.34	80	20	78·4	11·31	2·44	2·23	4·67	1·23	5·90	2·48	0·115	,,	20·2
3.1.35	87	20	97·0	11·75	2·37	2·09	4·46	2·17	6·63	2·26	0·116	,,	18·7
10.1.35	94	20	101·7	12·46	2·56	2·14	4·70	2·70	7·40	2·07	0·108	,,	19·2
17.1.35	101	20	120·7	13·73	2·92	2·60	5·52	2·82	8·34	1·91	0·103	,,	16·6
24.1.35	108	20	126·8	14·34	3·09	2·56	5·65	3·09	8·74	1·69	0·0963	,,	13·8
30.1.35	114	20	128·6	15·25	3·22	2·60	5·82	3·57	9·39	1·74	0·101	,,	12·8
7.2.35	122	20	129·9	16·40	3·26	2·64	5·90	4·01	9·91	1·74	0·112	,,	11·5
12.2.35	127	20	138·0	17·83	3·16	2·46	5·62	5·80	11·42	1·78	0·110	,,	9·6
19.2.35	134	20	132·2	19·10	3·20	2·32	5·52	6·49	12·01	1·81	0·113	,,	8·4

Table V.

Analyses of Kelsey Plums during Growth. Sept. 1933 to Feb. 1934.
Orchard A.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 28th Sept.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Starch.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.		A.
28.9.33	0	325	0·29	15·06	0·48	0·33	0·81	. .	0·81	7·37	0·540	. .	20·90
5.10.33	7	200	1·25	14·01	0·73	0·54	1·27	0·036	1·31	5·53	. .	. .	26·40
12.10.33	14	126	3·23	12·01	1·05	0·53	1·58	0·02	1·60	5·22	0·270	. .	. .
24.10.33	26	80	7·64	11·47	1·40	0·98	2·38	0·02	2·40	4·76	0·220	. .	22·50
2.11.33	35	36	11·2	10·94	1·60	1·06	2·66	0·04	2·70	4·42	0·172	Much	21·90
16.11.33	49	25	17·5	11·14	1·84	1·55	3·39	0·11	3·50	4·37	0·155	Slight	17·70
5.12.33	68	25	31·5	10·17	. .	. .	. .	. .	. .	3·36	0·140	None	18·50
18.12.33	81	25	41·9	10·43	2·55	2·49	5·04	1·43	6·47	2·96	0·109	,,	22·40
5.1.34	99	25	60·6	11·34	2·80	3·95	6·75	2·45	9·20	2·27	0·113	,,	20·10
15.1.34	109	25	76·0	12·49	2·96	4·00	6·96	3·05	10·01	2·06	0·0912	,,	17·80
22.1.34	116	25	86·0	13·50	3·01	4·23	7·24	3·56	10·80	1·90	0·0950	,,	17·90
29.1.34	123	25	93·0	15·40	3·29	4·29	7·58	4·01	11·59	1·83	0·0996	,,	13·30
8.2.34	133	25	100·4	16·51	3·14	4·28	7·42	4·69	12·11	1·72	0·0913	,,	11·97

Table VI.

Analyses of Kelsey Plums during Growth. Oct. 1933 to Feb. 1934.
Orchard B.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 17th Oct.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	S.	Ss.	St.	R.	N.	A.
17.10.33	0	122	2·79	12·20	0·76	0·63	1·39	·05	1·44	4·99	0·367	25·00
5.12.33	49	35	24·5	10·35	2·21	2·17	4·38	1·00	5·38	3·80	0·175	22·70
21.12.33	65	30	35·1	9·79	2·33	2·62	4·95	1·41	6·36	3·19	0·153	22·2
10.1.34	85	28	67·6	10·35	2·44	2·84	5·28	2·11	7·39	2·22	0·124	20·50
22.1.34	97	28	96·6	12·36	2·49	3·04	5·53	2·85	8·38	1·90	0·107	19·20
5.2.34	111	28	94·4	13·74	2·52	3·00	5·52	4·69	10·21	1·55	0·117	14·80
8.2.34	114	26	. .	. .	2·46	3·26	5·72	5·53	11·25	1·60	0·0968	13·14
15.2.34	121	26	. .	16·03	2·55	2·89	5·44	6·00	11·44	1·57	0·0879	13·80

TABLE VII.

ANALYSES OF KELSEY PLUMS DURING GROWTH. OCT. 1933 TO FEB. 1934. ORCHARD C.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 24th Oct.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.	A.
24.10.33	0	300	0·58	13·22	0·46	0·37	0·83	..	0·83	5·71	0·367	24·20
3.11.33	10	120	2·75	10·47	0·86	0·52	1·38	0·04	1·42	4·66	0·214	21·30
10.11.33	17	100	3·49	10·52	..	..	..	..	..	4·44	..	..
16.11.33	23	70	5·62	10·88	1·21	0·50	1·71	0·10	1·81	4·58	0·163	18·70
30.11.33	37	35	11·0	11·88	1·38	0·72	2·10	0·20	2·30	4·80	0·162	28·10
18.12.33	55	35	15·1	10·76	1·87	1·22	3·09	0·46	3·55	4·21	0·141	26·40
4.1.34	72	35	23·0	11·38	2·23	1·62	3·85	1·10	4·95	3·38	0·125	26·30
22.1.34	90	35	45·9	12·15	2·37	2·53	4·90	1·85	6·75	2·51	0·109	24·50
5.2.34	104	28	64·1	13·78	2·54	2·99	5·53	2·67	8·20	2·09	0·107	22·70
15.2.34	114	26	70·0	12·78	2·64	3·32	5·96	3·05	9·01	1·86	0·1025	17·30
22.2.34	121	25	..	14·26	2·73	3·53	6·26	3·62	9·88	1·68	0·099	16·40
1.3.34	128	25	..	14·47	2·80	3·92	6·72	4·20	10·92	1·68	0·0945	14·50

TABLE VIII.

ANALYSES OF GAVIOTA PLUMS DURING GROWTH. OCT. 1933 TO JAN. 1934. ORCHARD A.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 5th Oct.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Starch.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.		A.
5.10.33	0	220	0·26	11·48	0·44	0·16	0·60	0·05	0·65	6·05	0·538	..	..
12.10.33	7	270	0·94	12·20	0·54	0·16	0·70	0·05	0·75	5·79	0·440	..	21·20
24.10.33	19	100	3·27	11·00	0·75	0·29	1·04	0·16	1·20	4·66	0·280	..	16·30
2.11.33	28	60	6·35	9·92	0·87	0·83	1·70	0·10	1·80	4·42	0·219	Much	18·50
16.11.33	42	40	12·6	10·13	1·37	0·81	2·18	0·15	2·33	4·06	0·191	Slight	..
5.12.33	61	35	24·5	9·55	1·84	1·39	3·25	1·09	4·34	3·09	0·134	None	25·04
18.12.33	74	30	40·3	10·10	2·36	1·64	4·00	1·96	5·96	2·38	0·126	,,	27·20
8.1.34	95	30	55·3	12·30	2·76	2·67	5·43	4·09	9·52	1·82	0·121	,,	22·80
16.1.34	103	30	54·7	13·24	3·17	2·57	5·74	4·39	10·13	1·87	0·127	,,	22·30

Table IX.

Analyses of Gaviota Plums during Growth. Nov. 1934 to Feb. 1935.
Orchard C.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 8th Nov.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Starch.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.		A.
8.11.34	0	130	3·98	11·61	1·49	0·82	2·31	0·27	2·58	4·59	0·230	Much	19·15
15.11.34	7	50	12·0	11·34	1·64	1·00	2·64	0·07	2·71	4·32	0·185	,,	19·10
22.11.34	14	40	17·3	10·18	1·56	0·95	2·51	0·10	2·61	3·99	0·176	,,	18·50
28.11.34	20	26	22·0	10·58	1·70	1·08	2·78	0·17	2·95	3·99	0·175	,,	19·80
5.12.34	27	25	26·4	10·12	1·86	1·12	2·98	0·08	3·06	3·78	0·155	,,	21·00
12.12.34	34	25	37·3	10·01	2·11	1·24	3·35	0·30	3·65	3·38	0·149	Slight	20·10
20.12.34	42	20	49·1	10·76	2·16	1·97	4·13	0·76	4·89	2·97	0·135	None	21·38
27.12.34	49	20	60·5	11·18	2·34	2·18	4·52	1·10	5·62	2·49	0·116	,,	21·55
3.1.35	56	20	76·7	11·67	2·26	1·97	4·23	2·63	6·86	1·97	0·109	,,	21·55
10.1.35	63	20	98·7	12·31	2·41	1·96	4·37	3·27	7·64	2·00	0·107	,,	19·95
17.1.35	70	20	112·0	13·72	2·74	2·23	4·97	3·84	8·81	1·78	0·107	,,	18·30
24.1.35	77	20	121·2	15·87	2·67	2·26	4·93	5·74	10·67	1·70	0·112	,,	12·80
30.1.35	83	20	122·7	16·34	2·73	1·97	4·70	6·46	11·16	1·57	0·118	,,	11·98
7.2.35	91	20	101·1	17·44	2·75	1·97	4·72	6·60	11·32	1·73	0·123	,,	10·16

Table X.

Analyses of Gaviota Plums during Growth. Oct. 1933 to Jan. 1934.
Orchard C.

All results expressed as percentages of Fresh Weight.

Date of analysis.	Days from 24th Oct.	No. of fruits per sample.	Mean weight per fruit.	Dry weight.	Glucose.	Fructose.	Reducing sugars.	Sucrose.	Total sugar.	Alcohol insol. residue.	Total nitrogen.	Starch.	Acidity in c.c. N/1.
			Gm.	W.	G.	F.	Sr.	Ss.	St.	R.	N.		A.
24.10.33	0	165	1·15	12·06	0·98	0·32	1·30	0·06	1·36	5·54	0·325	..	23·80
3.11.33	10	70	5·54	9·85	1·44	0·34	1·78	0·07	1·85	4·50	0·223	..	18·50
10.11.33	17	45	8·17	9·87	..	..	..	..	..	4·20	..	..	..
16.11.33	23	35	12·4	11·23	1·63	0·70	2·33	0·09	2·42	4·32	0·178	..	23·90
30.11.33	37	30	22·2	10·62	2·24	1·29	3·53	0·87	4·40	4·12	0·151	Much	27·7
18.12.33	55	28	39·3	9·86	2·60	2·24	4·84	1·90	6·74	2·90	0·117	None	24·2
4.1.34	72	26	65·6	11·15	2·77	2·92	5·69	2·71	8·40	2·09	0·0930	,,	23·3
10.1.34	78	26	78·2	11·73	2·80	2·96	5·76	2·87	8·63	1·88	0·0990	,,	19·6
14.1.34	82	26	84·0	12·58	2·91	2·98	5·89	2·81	8·70	1·76	0·0964	,,	20·2

During the 1933–34 season the course of chemical change in the Kelsey plums was traced in three orchards, while for the Gaviota plums only two orchards were used. It became evident during that season that for the accurate interpretation of results more frequent analyses were essential, and consequently in the 1934–35 season the number of analyses during the growth period was doubled. In the second season, however, the plums were taken from only two orchards.

Figs. 2 and 3 show the two sets of results obtained during the second season.

The gathering of plums began about a fortnight after "setting." It was impossible to collect a sample at an earlier stage, as the setting period for both varieties of plums is irregular and somewhat prolonged. Crop failure in the 1934–35 season did not allow any gathering of Gaviota plums until each fruit weighed as much as 4 grams.

Changes in Weight during Growth.—The increase in weight of the fruit was followed throughout the season by weighing the sample selected for analysis and determining the mean weight per plum.

The curves shown in fig. 4 are typical of the results obtained in both seasons. All absorption curves are S-shaped in form. They show an initial short period of comparatively slow growth. This is followed by a stage of rapid and constantly increasing rate of growth, which finally reaches a maximum. It will be shown later that the end of this second stage marks the beginning of the period of ripening of the fruit.

These two stages were of variable length, depending on variety and season. For Kelsey plums each stage was of approximately sixty days' duration, for Gaviota plums only thirty-five days. During the 1934–35 season the average rates of increase of weight * during the first stage were 0·5 gram per day for Kelsey and 0·80 gram per day for Gaviota plums. During the second stage these rates rose to a maximum of 2·0 and 2·7 grams per day respectively. The corresponding maximum figures for the 1933–34 season were 1·40 and 1·80 grams per day. In general, Gaviota plums showed a higher rate of growth than Kelsey plums, but as their growth period was shorter their maximum weight was less than that of the Kelsey (*e.g.* 119 grams per fruit compared with 132 grams in 1934–35).

A stage of maturation followed the two periods described above. This final stage in the life of the fruit was characterised by a rapid fall from the

* Rate of growth was calculated as follows: Smooth curves of changes in weight per fruit were drawn in a manner similar to those shown in fig. 4. From the resulting curves the amounts at intervals of five days were obtained and the mean increase per day during those intervals calculated. The curve of rate of increase was then obtained by plotting the results against time.

maximum rate of growth (as measured by increase in weight) to zero in a period of approximately twenty-five days. A factor which contributed towards this rapid fall was an increasing loss due to transpiration. Copeman (13) records a similar loss of weight during the final ripening stages of oranges. During the last fortnight Kelsey plums showed a constant water content, which can only be interpreted as indicating that water lost in transpiration was exactly balanced by water supplied by the tree. Although the plums showed no water intake the dry weight per fruit continued to increase. Unfortunately, it was impossible to collect Kelsey plums in an advanced state of ripeness, as they rapidly succumbed to "Kelsey Spot" if left to ripen on the tree. Samples of Gaviota plums, however, were collected until the plums fell naturally from the trees. These plums also showed no increase in water content at the end of the ripening period although the dry weight per fruit was rising. Thus, during the ripening period increase in weight per fruit was reduced to almost zero, yet growth as measured by increase in dry-weight content per plum was still proceeding at a fair rate.

Starch Content and Growth of Stone.—From Tables IV–X it will be seen that starch made but a brief appearance in the Kelsey plum and was found in small quantities only. During the 1934–35 season the first occurrence of starch was observed on 18th October. Its content rose to a maximum on about 1st November and almost disappeared on the 8th of the same month. In Gaviota plums the apparent concentration of starch was greater and present over a longer period than in Kelsey plums. When picked on the 8th November the first Gaviota sample showed a considerable amount of starch, which disappeared completely between the 12th and 20th December.

Increase in the fresh weight of the stone was followed during the 1934–35 season with as great an accuracy as possible. The results are shown graphically in fig. 1. The considerable scatter of the points is due entirely to the difficulty of separating all adhering flesh, especially during the early periods when the outer core was very soft and indeterminate.

The rate of increase in weight of the stone was high in the beginning, and the maximum weight was reached in both varieties on about the 5th December. From then onwards the weight per stone slowly decreased throughout the rest of the fruit's life. The maximum weight per Kelsey stone was about 2 grams, whereas that of the Gaviota stone reached a maximum of only 1·3 grams.

The period of rapid growth and hardening of the stone corresponded to a low rate of growth (as measured by increase in weight) of the pulp of the fruit. The stone seemed to be the dominant tissue of the fruit during that period. This confirms a similar observation by Lott (35) on Hiley peaches.

As soon as the stone hardened and reached its maximum weight the rate of increase in weight of the pulp rose sharply, thus marking a definite period in the life of the fruit.

Changes in Dry Weight.—The changes in dry-weight concentration (W) of Kelsey and Gaviota plums are shown in figs. 2 and 3. The curves obtained are similar in all sets of observations. In the first stage of growth the concentration fell at a decreasing rate. It has already been pointed out

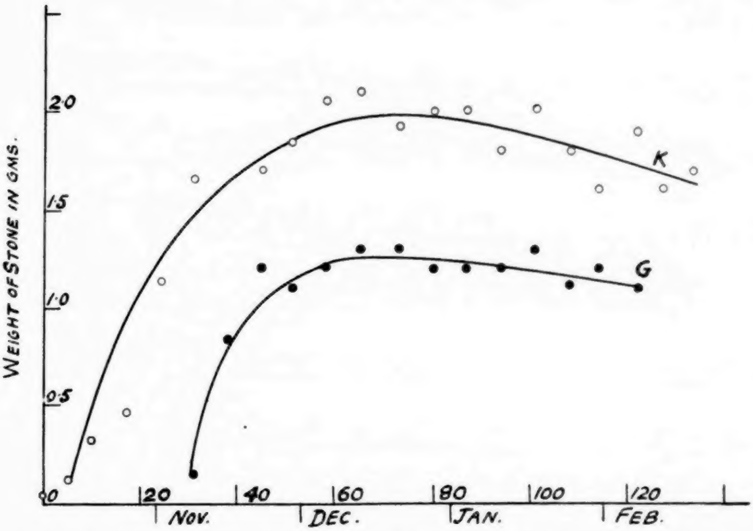


FIG. 1.—The change in the fresh weight of the plum stone during growth in the 1934–35 season. K = Kelsey plums. G = Gaviota plums.

that during the initial period of growth of the plum the stone was the dominating factor. This was reflected in the slow growth rate of the pulp and consequent slow accumulation of total solids. In Kelsey plums (fig. 2) dry-weight concentration fell from 13·60 per cent. to 10·23 per cent. within the first sixty days, this period corresponding to the growth period of the stone. Thereafter the concentration of total solids increased steadily, and the last samples showed as much as 19·10 per cent. dry weight.

The rate of intake of total solids per fruit in grams per day increased sharply after the stone was fully grown (fig. 6), and continued increasing at a constant rate until a maximum rate was reached. Thus during the first sixty days, when intake of total solids in Kelsey plums was slow, the rate of increase of dry weight amounted to no more than 0·03 to 0·11

grams per day, but during the next thirty-five days the rate rose to 0·3 gram per day.

The curve of rate of increase of dry weight follows, in general, the curve of rate of growth of the plum as measured by increase in total weight

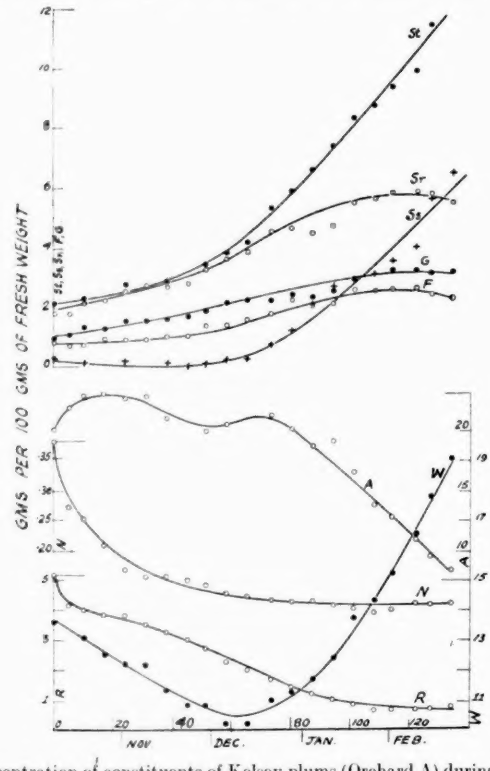


Fig. 2.—Concentration of constituents of Kelsey plums (Orchard A) during growth. Oct. 1934–Feb. 1935. W = Dry weight. R = Alcohol insoluble residue. N = Nitrogen. A = Acidity in c.c. N/1. F = Fructose. G = Glucose. Ss = Sucrose. Sr = Reducing sugars. St = Total sugars.

(fig. 6). The two curves are almost parallel, the dry-weight-rate curve lagging about twenty days behind for Kelsey and about twelve days for Gaviota plums. Thus, the maximum rates of increase of total solids for the two varieties occurred, in 1935, on 1st February and 17th January respectively, while the corresponding maxima for growth rates occurred on 14th January and 7th January. The last-mentioned dates were coincident with the beginning of translucency and yellowing of the

base of the plums. This is a precursor to the appearance of the first flush of colour and indicates the beginning of the ripening stage. During the ripening stage the rate of increase of total solids fell rapidly, and when the

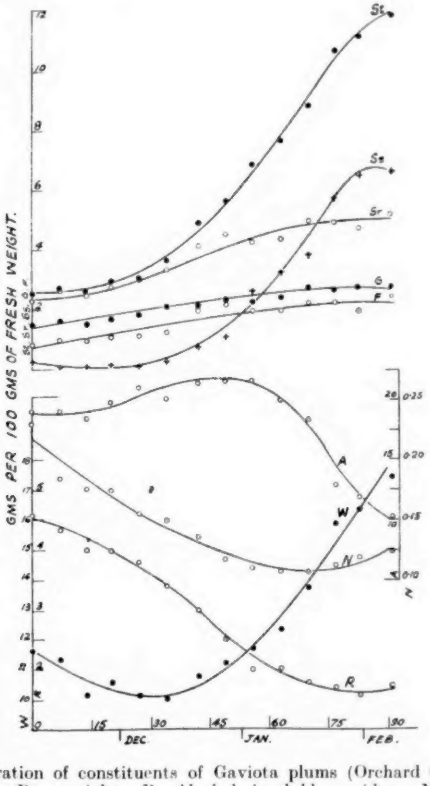


FIG. 3.—Concentration of constituents of Gaviota plums (Orchard C) during growth. 1934–35. W = Dry weight. R = Alcohol insoluble residue. N = Nitrogen. A = Acidity in c.c. N/1. F = Fructose. G = Glucose. Ss = Sucrose. Sr = Reducing sugars. St = Total sugar.

last samples of plums were gathered the total dry weight per fruit was increasing very slowly. Growth (as measured by increase in weight) had ceased, however, ten days before the final gathering.

With the cessation of growth senescence set in. On the tree it was characterised by the softening of the fruit, by an increase in colour, and sometimes even by the splitting of the skin.

Commercial picking of the plums for export usually begins when the

maximum rate of growth has been reached. The fruit is not then at its maximum weight and total solids are still increasing.

Changes in Alcohol Insoluble Residue.—The concentration of alcohol insoluble residue (including starch) fell continuously during growth. In Kelsey plums (fig. 2) a high rate of fall was observed during the first ten days. With the appearance of starch on 18th October the rate of fall in concentration diminished, but increased again on about the 8th November, by which time the starch had been almost completely hydrolysed. During the last stages of growth the rate of fall in concentration was slow, and on 9th January the concentration reached an almost constant value.

In Gaviota plums (fig. 3) the initial rapid rate of fall in concentration was not observed, as the plums contained starch when the first sample was gathered. With the completion of starch hydrolysis on 12th December an increased rate of fall in the concentration of alcohol insoluble material was observed in this set. In the final stages the change in concentration was very small.

Similar changes were observed in the remaining sets of analyses. Archbold (5) observed a similar rapid rate of fall in the concentration of the alcohol insoluble material of apples in the initial stages of growth before the beginning of starch synthesis. She also reports that in the apple the accumulation of alcohol insoluble residue is very rapid and takes place within the first few weeks after setting (4). Copeman found a similar occurrence in the orange (13). In the plum, however, this period is somewhat prolonged (fig. 5). It would seem that this is due to the extra material required for the stone, as in four out of the seven sets of analyses it was found that the rate of accumulation of alcohol insoluble residue dropped rapidly when the stone was fully developed (fig. 6). (In the other three sets the evidence is not conclusive.)

The total period of observed growth of Kelsey plums (fig. 2) was one hundred and thirty-four days. During the first sixty days the rate of accumulation of alcohol insoluble residue rose steadily, and reached a maximum rate of 0·03 gram per fruit per day on 7th December. From fig. 1 it can be seen that this date corresponds with the maximum weight reached by the stone. Thereafter the rate of intake of alcohol insoluble material fell rapidly and became zero when growth stopped. The total amount of alcohol insoluble material accumulated during the first sixty days was 1·425 grams as compared with 2·35 grams per fruit present in the plum at maturity. The accumulation of the alcohol insoluble material in the pulp during the early period of growth of fruits is mostly attributable to the cell-wall materials needed for cell division. From this it can perhaps be deduced that the period of cell division in the plum is of longer duration than in the apple or the orange, as the corresponding periods of rapid

accumulation of alcohol insoluble material is longest in the plums. This might be due to the influence of the stone, which demands large quantities of alcohol insoluble material during its growth. When the stone is fully developed the fruit has only to cope with the continually diminishing supply for cell growth; hence the observed rate of formation of alcohol insoluble compounds falls rapidly.

Changes in Acidity.—The acid concentration rose in the Kelsey plums during the first two weeks and reached a maximum concentration equivalent to 23·2 c.c. normal acid per 100 grams of pulp (fig. 2). This was coincident with the beginning of starch synthesis. Thereafter acid concentration fell until starch hydrolysis was complete, when the concentration rose again to a maximum of 21·4 c.c. normal acid per 100 grams of pulp, and then rapidly declined throughout the remainder of the growth period. The first rise in concentration of acid, before the beginning of starch synthesis, was not observed in the remaining sets of results. The collection of samples should have begun much sooner after the setting of the fruit, as this period of rise of acid concentration is of very short duration. The second rise in acidity, which took place after completion of starch hydrolysis, was observed in four more instances (Tables VII–X).

The changes in the amounts of acid per fruit are shown in fig. 4. The acidity per plum rose rapidly, and reached its maximum value simultaneously with that of alcohol insoluble residue. Thereafter the acid per fruit dropped rapidly.

The changes in the rate of acid accumulation shown in fig. 6, together with the changes described above, bring out an interesting relationship between acid, starch, and alcohol insoluble residue. Thus, for Kelsey plums the rate of acid accumulation rose during the first two weeks but became almost steady with the appearance of starch. With the completion of starch hydrolysis the rate of increase of acid per fruit again rose, and thereafter paralleled the curve of alcohol insoluble residue.

It would seem, therefore, that the production of alcohol insoluble materials in the fruit in the form of cellulose or hemicellulose is accompanied by formation of organic acids. This suggests that both materials have a common origin. Starch appears to be formed alternatively to acids. Archbold (5) has made similar observations in the apple, and suggests that the alcohol insoluble materials and acids are alternative condensation and oxidation products of a part of the entering carbohydrates, presumably sugars.

It will be observed from fig. 6 that the curves for rates of increase of acidity, dry weight, and weight per fruit are very similar. These curves signify that the rate of acid formation was low when rate of growth was low, and that the rate of production of acid was high when growth was rapid.

The rate of acid accumulation actually dropped to zero after the plums reached their maximum rate of growth.

If acid is formed from the condensation products of some entering sugar, starch formation during the early growth phase of the plum could be explained on the assumption that low rate of acid storage during that period resulted in these condensation products exceeding some critical concentration.

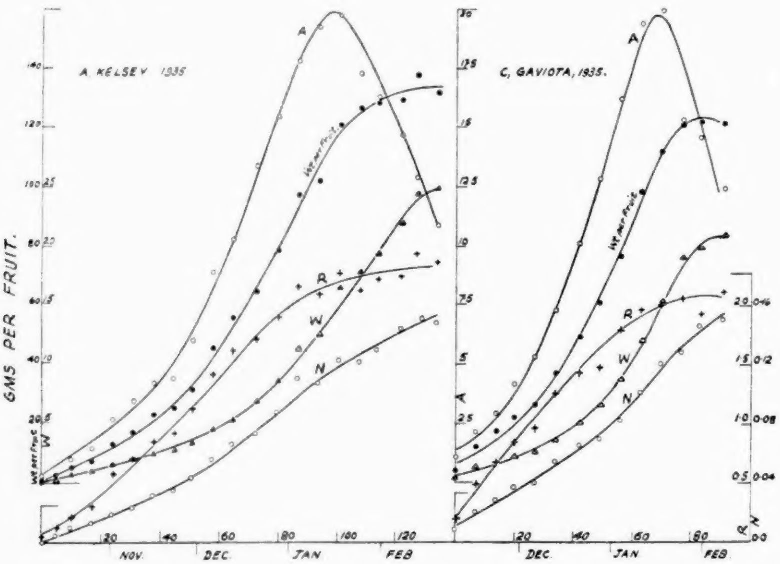


FIG. 4.—Changes in amounts per fruit of constituents of Kelsey and Gaviota plums during growth. W = Dry weight. R = Alcohol insoluble residue. N = Nitrogen. A = Acidity in c.c. N/1.

Changes in Nitrogen Content.—The concentration of nitrogen in the pulp fell rapidly during the initial period of growth. It then diminished at a decreasing rate until it reached a constant value (figs. 1 and 2). This constant value was correlated with a decreasing rate of growth of the fruit.

The total amount of nitrogen per fruit increased continuously throughout the whole growth period. The rate of nitrogen accumulation in the pulp was comparatively slow during the growth phase of the stone. Thus, at this stage, nitrogen increased at the rate of 0·7 mgm. per day in the Kelsey plums and 1·2 mgms. per day in the Gaviota plums. Lott (35) has shown that during the initial growth period of the Hiley peach the rate of accumulation of nitrogen was slow in the flesh of the peach but high in the

stone and kernel. Similar conditions probably obtain also in the plum, the slow rate of absorption of nitrogen in the pulp being due to the high demand for nitrogen for stone and kernel growth. When the stone was fully grown a rise in the rate of nitrogen intake in the flesh was observed. It rose to a maximum of 1·60 mgms. and 2·6 mgms. per day per fruit for the Kelsey and Gaviota plums respectively. These maxima coincided with the maxima of the rates of dry-weight increase in the pulp. Thereafter the rate of nitrogen accumulation declined but did not reach zero.

As far as the present observations go it would seem that nitrogen continues to be absorbed by the fruit as long as it remains on the tree. Towards the end of the growing season the loss of water by transpiration became considerable. On calculating the weight of water per fruit * it was found that the last samples of both Gaviota and Kelsey plums in the second season showed no gain in water content, *i.e.* water intake only balanced transpiration loss. As at that time the rate of nitrogen intake was still high, a rise in nitrogen concentration could be expected. In fig. 3 it will be seen that such a rise in nitrogen concentration actually did take place in the Gaviota plums. A similar rise in nitrogen concentration was observed in the first season in Gaviota plums from orchard A. As high concentration of nitrogen is said to have an unfavourable effect on the keeping quality of fruit (25), the observed rise in nitrogen concentration might have an important practical bearing on orchard practice. The high temperature prevalent in the orchard no doubt induced a high transpiration rate in the leaves as well as in the fruit, with the resulting rise in nitrogen concentration. Generous irrigation of the orchard at that time might possibly restore the balance.

Archbold (4) reports that most of the nitrogen of the apple is stored in the early period of growth. Howlett (28), and Plagge, Maney, and Gerhardt (41) have made similar observations. In this respect the plum and the peach (35) differ from the apple. Nitrogen was stored in these fruits throughout the growth season.

In the plum changes in the rate of nitrogen accumulation were parallel with changes in the increase of dry weight (fig. 6). This observation fits in with the general conception of the effect of nitrogen on growth and with the results of other workers (11, 21). Appleton and Helms (6) found that there was a close relationship between the rate of growth and the rate of nitrogen intake of oats and cotton.

A consideration of the changes in potash and phosphate is outside the scope of these discussions. Potash, however, is known to aid in the production and translocation of carbohydrates, while phosphate forms an integral part of the cell nucleus. The effect of nitrogen on these two

* Weight of water per fruit = Wt. of fruit − wt. of stone − dry wt.

elements is therefore of importance. Cohen (12) shows that a constant relationship exists between the potash and phosphate contents of plums.* Using Cohen's figures for potash and phosphate, it is found that the nitrogen/potash and nitrogen/phosphate ratios are also constant. These three elements must therefore be in some definite state of equilibrium in the fruit. Conditions which affect the rate of accumulation of nitrogen in the fruit will therefore be reflected in the potash and phosphate content, and hence also in the growth of the fruit. This view is supported by the findings of W. Thomas (44), who observed that for apple trees omission of any nutrient element from the complete fertiliser (P K N) was followed by a decreased absorption of the remaining elements. Such decreased absorption resulted in a nutritional lack of balance as exhibited in reduced growth of the tree.

Changes in Sugar Content.—The changes in the sugar content of the plums during growth could be divided into two clearly differentiated periods. The first stage lasted from petal fall until completion of the growth of the stone. This period was characterised by a slow rate of increase of total sugar and an almost complete absence of sucrose. The glucose concentration was high compared with that of fructose, which accumulated at a slower rate than glucose.

The second period lasted until the completion of cell growth, *i.e.* until a minimum rate of increase of weight of the fruit had been reached. This stage was characterised by a rapid increase in total sugars, due mainly to the rapid intake of sucrose. The concentration of reducing sugars increased very slowly and at a decreasing rate. Glucose concentration was still higher than fructose, but the rate of increase of the hexoses was almost the same.

The changes in the different sugar fractions of Kelsey and Gaviota plums during the 1934–35 season are shown in figs. 2, 3, and 4. There is a striking similarity between the curves for Gaviota plums and those for the Kelsey variety. These curves illustrate the general nature of the sugar changes in all the sets of plums examined during both seasons.

The actual quantitative changes in sugar content during growth are illuminating. Thus, for Kelsey plums (fig. 5) the total rise in glucose during the slow growth period of sixty days was 0·93 gram per fruit. During the same time the increase in fructose was only 0·61 gram, *i.e.* glucose accumulated about one and a half times as rapidly as fructose. During the second growth period of sixty days (by the end of which the rate of increase of weight per fruit dropped to almost zero) the total increase in glucose was 3·24 grams per fruit compared with an increase in fructose of

* The estimations of potash and phosphate content were carried out by Dr. Cohen on the samples used by the writer during this investigation.

2·67 grams per fruit. The ratio of glucose to fructose thus decreased considerably during this period. Similar relationships were found to hold for the Gaviota plums (fig. 3).

Towards the end of the growing season, when the fruit had passed its maximum growth rate, the rate of increase of reducing sugars fell off rapidly with a resulting drop in concentration. The rate of sucrose absorption, however, did not alter. From figs. 2, 3, and 5 it will be seen that its rate of

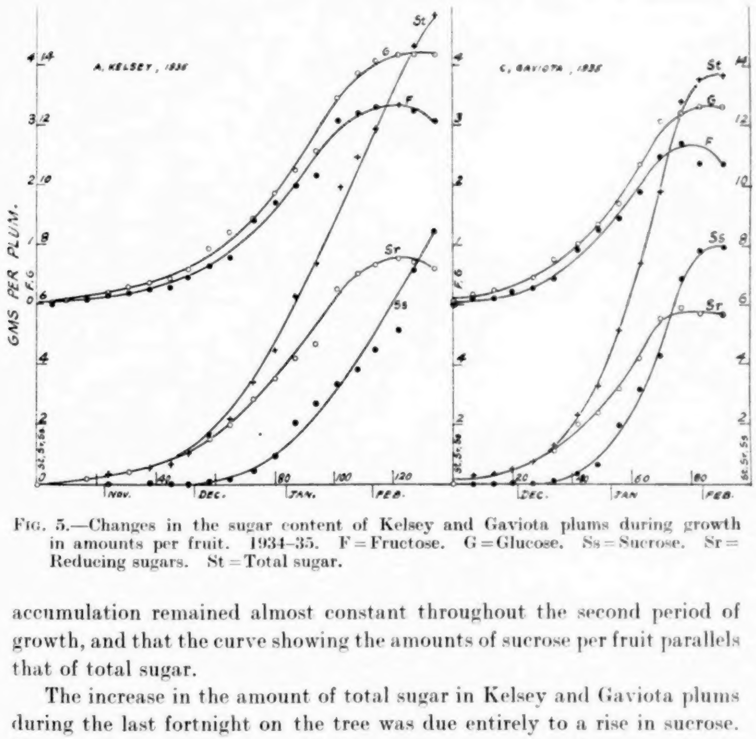


Fig. 5.—Changes in the sugar content of Kelsey and Gaviota plums during growth in amounts per fruit. 1934–35. F = Fructose. G = Glucose. Ss = Sucrose. Sr = Reducing sugars. St = Total sugar.

accumulation remained almost constant throughout the second period of growth, and that the curve showing the amounts of sucrose per fruit parallels that of total sugar.

The increase in the amount of total sugar in Kelsey and Gaviota plums during the last fortnight on the tree was due entirely to a rise in sucrose. During this period the increase in dry weight was equal to the accumulation of sugars alone. Since increase of sugars in the plum takes place without any marked lessening of rate until the very end of the observed life of the fruit, it would seem that translocation of sugars into the plum takes place as long as it remains on the tree. The falling off in the absolute amounts of reducing sugars at this time indicates a possible synthesis of sucrose from the stored hexoses. That alone, however, would not account for the total rise in sucrose content. If it is assumed that sucrose is the sugar of

translocation, then it would seem that sucrose entering the fruit at this time undergoes no subsequent hydrolysis in the plum.

The Interrelationship of the Sugar Fractions.—In a previous paper (16) it was indicated that internal breakdown of plums kept in cold storage is intimately connected with changes in the relationship of the sugar fractions. It was observed that a reversal of the sugar equilibrium accompanies the onset of internal browning. The bearing of the changes in the sugar

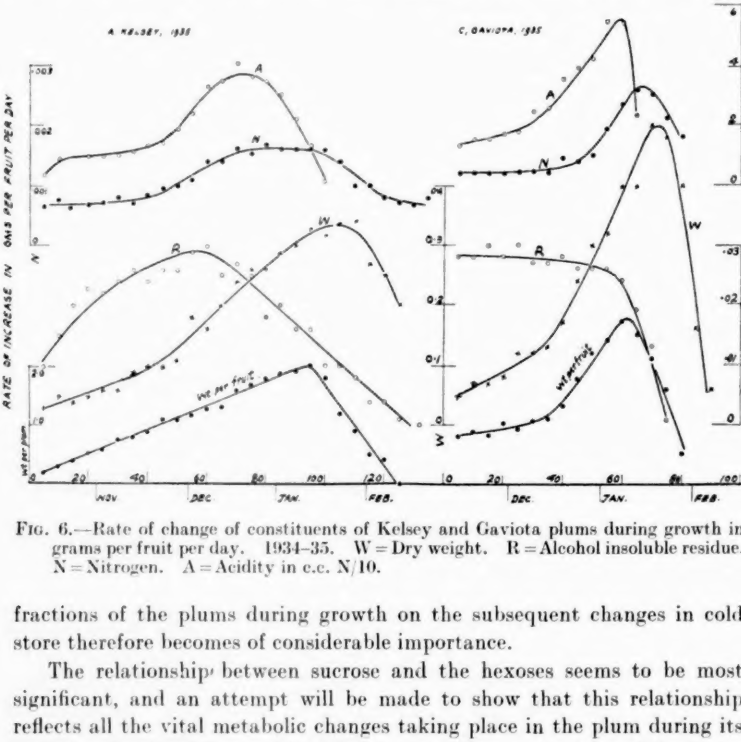


FIG. 6.—Rate of change of constituents of Kelsey and Gaviota plums during growth in grams per fruit per day. 1934–35. W = Dry weight. R = Alcohol insoluble residue. N = Nitrogen. A = Acidity in c.c. N/10.

fractions of the plums during growth on the subsequent changes in cold store therefore becomes of considerable importance.

The relationship between sucrose and the hexoses seems to be most significant, and an attempt will be made to show that this relationship reflects all the vital metabolic changes taking place in the plum during its growth. In the absence of knowledge as to the exact nature of the interactions between the different sugars which take place in plant metabolism, any suggestions that may be made regarding these interactions must of necessity be tentative.

During the first phase in the life of the plum active cell division is at its highest, and consequently enzyme activity and rate of respiration are also very high (31). A considerable demand exists at this stage for cell-wall material, but the rate of acid accumulation is slow because the rate of growth

(as measured by increase in dry weight) is also slow. During this period it was observed that no sucrose accumulated in the plum but that the hexoses increased slowly. If it is assumed that sucrose is the sugar of translocation, then it would appear that at this stage the entering sucrose is rapidly hydrolysed according to the reaction

$$\text{sucrose} \rightleftharpoons \text{glucose} + \gamma\text{-fructose},$$

in order to supply the glucose necessary for cell-wall formation and the γ-fructose for respiration (11, 31, 39). It has already been indicated that starch formation at this stage could be accounted for if the condensation products of glucose exceed some critical concentration inasmuch as the observed rate of acid synthesis is slow. The lower rate of fructose storage observed in the fruit could be accounted for by the reaction

$$\text{normal fructose} \rightleftharpoons \gamma\text{-fructose} \rightleftharpoons \text{glucose},$$

proceeding preferentially in a forward direction.

In the beginning of the second phase of growth active cell division rapidly slows down, and with it the rate of respiration and enzyme activity also decrease. Considerable amounts of cell-wall material are still laid down by the expanding cells, while synthesis of organic acids proceeds rapidly. Towards the end of this period the cells reach their maximum size and cell-wall formation ceases. Enzyme activity in the living cell, which has been progressively declining throughout this phase, now reaches its minimum value.

Corresponding to these changes, the rate of accumulation of the hexoses was observed to rise in the beginning of this stage; these sugars reached their maximum value when cell growth stopped. The rise in fructose storage can be accounted for by the decreasing rate of respiration, and the rise in glucose by the decreased demand on glucose for cell-wall materials. Since a considerable amount of acid was formed during this period the rise in glucose would be proportionally smaller than that of fructose. As has been previously indicated, the fructose/glucose ratio was higher in the second period of growth than in the first.

The rapid rise in sucrose during the second phase can be taken to be the result of the decreasing enzyme activity, resulting in the hydrolysis of continually decreasing amounts of the entering sucrose. When cell growth, as evidenced by the increase in weight and absorption of alcohol insoluble materials, stopped at the end of this period, sucrose hydrolysis ceased completely. It is significant that the production of acid stopped shortly before this stage was reached.

If acid formation is a result of enzyme activity in the cell, then the cessation of acid formation may be taken as an indication that this activity had now reached a minimum. The complete cessation of sucrose hydrolysis

which was observed to take place soon afterwards would then represent the culmination in the cell of the activity which is responsible for the condensation and oxidation of sugars to acid.

The end of the second phase of growth thus marks the completion of cell activity peculiar to growth, and the beginning of the maturation period. During the observed portion of this period on the tree, sucrose rapidly accumulated but reducing sugars declined. Fructose was the sugar lost at this stage, presumably being used for respiration, whilst glucose (in amounts per fruit) remained constant (fig. 5). It is quite probable, however, that towards the end of this period the hexoses begin to change back into sucrose, for it has been observed that in cold storage the reaction

$$\text{glucose} + \gamma\text{-fructose} \rightleftharpoons \text{sucrose}$$

proceeds rapidly in a forward direction (16). The observed reversal of this reaction when internal breakdown occurs in cold storage now assumes an added significance. It points to the conclusion that internal breakdown will take place in plums as soon as conditions arise to alter the course of chemical change which normally takes place during the maturation period on the tree.

Varietal Differences in the Plums.

The striking similarity between the concentration and absorption curves of Kelsey plums and those of Gaviota plums definitely indicates that the nature of the changes during growth are essentially the same in both varieties. The rates of growth and accumulation of materials, however, differ largely. The life on the tree of the Kelsey plum, from petal fall until picking time, is in the neighbourhood of one hundred and forty days, that of the Gaviota plum only about eighty days. Yet within these different periods the plums grow to very nearly the same size. Thus, in the 1934–35 season the respective weights of Kelsey and Gaviota plums at picking time were 112 and 130 grams. The latter variety "sets" about a fortnight later than the Kelsey plum and is harvested three weeks earlier. During its shorter life on the tree its reserve materials accumulate more rapidly than they do in the Kelsey plum.

In Table XI a comparison is given of some of the more outstanding differences between the two varieties of plums. Although the rate of absorption of reserve materials in the Gaviota plum is greater than in the Kelsey, the actual concentration of the various materials is higher in the Kelsey. Thus, at the same stage of maturity the Kelsey plums contained 12·01 per cent. total sugar compared with 10·67 per cent. in the Gaviota. Nitrogen concentration was almost the same in both varieties (0·1128 per cent. in the Kelsey and 0·1118 per cent. in the Gaviota). Dry-weight

percentage was much greater in Kelsey plums. These contained 17·83 per cent. total solids at picking time compared with 13·83 per cent. in Gaviota plums. The Gaviota variety, however, contained more acid, the acidity figures for the same stages of maturity being 12·8 and 11·0 c.c. N/1 acid per 100 grams fresh weight.

TABLE XI.

Observation.	Kelsey.	Gaviota.
Growth period .	Approximately 140 days	Approximately 80 days
Stone growth period	Approximately 60 days	Approximately 30 days
Maximum rate of growth.	2·0 grams per day per fruit	2·70 grams per day per fruit
Maximum rate of nitrogen intake.	1·7 mgms. per day per fruit	2·60 mgms. per day per fruit
Maximum rate of potash intake.	3·4 mgms. per day per fruit	5·10 mgms. per day per fruit
Maximum rate of acid intake.	0·41 c.c. N/1 per day per fruit	0·55 c.c. N/1 per day per fruit
Sugar content at maturity.	15·70 grams per fruit	12·83 grams per fruit
Acid content at maturity.	10·95 c.c. N/1 per fruit	15·40 c.c. N/1 per fruit

The Gaviota and Kelsey plums thus differ considerably with respect to chemical composition and rate of metabolic activity, yet the nature of these metabolic changes is the same. It has been shown in a previous publication (16) that this close similarity in the chemical nature of the metabolism is no longer maintained in cold storage. Furthermore, Gaviota plums exhibit better keeping quality in cold storage if picked early in their maturation period; the contrary holds for Kelsey plums (15, 14).

These observed differences of behaviour in cold storage are quite unexpected. A possible explanation might lie in the observation that maturity has a different effect on the total nitrogen content of the two varieties of plums. The commercial picking of Gaviota plums in 1935 began on the 10th January. Within fourteen days the plums remaining on the trees became fully ripe and showed an increase of 28·3 per cent. in the nitrogen content per fruit. The corresponding rise in the nitrogen content of Kelsey plums was only 2·4 per cent. in a fortnight of ripening on the tree after the 7th February, when commercial picking of these plums commenced. The evidence collected by Kidd, West, and co-workers (42) points to a direct relationship between nitrogen content and respiration. The rapid rise of

the nitrogen content of the ripening Gaviota plums might thus account for the fact that the greener plums had a longer storage life than the more mature plums. Until a complete investigation into the nature of the nitrogen fractions entering the plums during growth has been made, however, no definite conclusions can be drawn from the above observations.

The Effect of Seasonal and Climatic Variations on the Course of Growth and Chemical Composition of Plums at Maturity.

The available data covers only a period of two years, but the weather conditions in the two seasons differed considerably. The winter of 1934 (May–August) was much warmer than that of the preceding year, and there was also less rainfall. In 1933–34 both the Kelsey and the Gaviota trees bore a good crop in all orchards, but 1934–35 was a season of delayed foliation. Consequently the Kelsey crop was poor, and estimated at 40 per cent. of the yield of the previous year. Gaviota trees failed to bear in orchard A and had a very poor crop in orchard B.

As a result, in the two orchards (A and C) under observation in the second season, the number of fruits borne by each tree was much smaller than in 1933–34. It is thus impossible to deduce with any certainty whether the observed differences in composition and during growth were due to seasonal effects, or whether these differences could not be obtained in any season by severe "thinning" of the fruit on the trees.

In the second season the Kelsey plums were collected from orchard A, the Gaviota plums from orchard C. A comparison of the dates of setting in this season with those of 1933–34 showed a delay of about seven to ten days. The total length of the growth period was, however, almost identically the same in the two seasons. Thus, in the second season Kelsey plums were gathered on or about the 12th February and Gaviota plums on or about the 17th January, each about ten days later than in the previous season.*

Although the duration of the growth period did not differ materially in the two seasons, the plums in the second season reached a larger size than those in the first. The respective average weights of the Kelsey plums at commercial picking time were 132 grams and 96 grams. The rate of growth and the rate of accumulation of materials in the plum were much greater in the second season than in 1933–34. During the first season the rate of increase in weight rose to a maximum of only 1·4 grams per fruit per day, but in the second season it rose to a maximum rate of 2 grams per day. It has already been indicated that nitrogen is a function of growth. As could

* Gathering of plums is usually spread over a period of fifteen to twenty days. The dates given correspond, therefore, only to "peak" or "middle" periods.

therefore be expected, the rate of nitrogen intake was also higher in the second season than in the first. The relevant maximum rates were 1·60 and 1·26 mgms. per day per fruit for the Kelsey plums.

Nitrogen.—A higher nitrogen content per plum was to be expected in the second season because of the relatively larger-sized fruits; but it was also observed that nitrogen concentration was higher in that year than in the previous season. This was most noticeable in Gaviota variety. The nitrogen concentration curves for the two seasons are almost parallel to each other, the 1935 graph showing an almost 10 per cent. higher nitrogen content throughout the growth period. The differences are not so great in Kelsey plums from orchard A, but they are significant. The higher nitrogen concentration of the plums in 1935 cannot be traced to any extra fertiliser treatment, as the Gaviota trees in orchard C, for instance, received identical nitrogen applications in both seasons. It seems, therefore, that the increase in nitrogen concentration and consequent increase in rate of growth per fruit are due to the smaller number of fruits per tree in the second season. Archbold (4) is of the opinion that supplies of nitrogen to apples may influence yield and size only, but will not alter the percentage of nitrogen in mature fruits. She has found that in successive seasons in unfertilised orchards the nitrogen concentration remained nearly constant while size and yield varied. Researches by other workers do not confirm Archbold's findings. Thus Wallace (45) has shown that the nitrogen content of apples is sometimes reduced to half of its original value as a result of nitrogen stárvation induced by growing grass in the orchard. Lott (34) has found that treatment of peach trees with sodium nitrate resulted in an increased percentage of nitrogen in the fruit. Gourley and Hopkins (22) also report an increase in nitrogen content of apples as a result of the application of sodium nitrate to the trees.

In the present investigation it was found that the nitrogen concentration in all the Kelsey plums picked in 1935 at export stage was higher than the concentration of nitrogen in plums picked in 1934 at the same stage of maturity (Table XII). As the cultivation practice was not altered in any of the orchards, the cause of this rise in nitrogen concentration might perhaps be found in the increased leaf area per plum available to the fruit in 1935 because of the poor crop. Although the path of translocation of nitrogenous compounds and the centre of the synthesis of protein in plants have not as yet been settled, it would seem that the nitrogen supply is elaborated in the leaves (39). Murneek and Harvey (38) found a relationship between leaf area on the spur and its nitrogen content. Hooker (27) and Howlett (28) have shown that nitrogen in the spur is directly transferred to the developing fruit. It might therefore be expected that an increase in the relative leaf area per plum would result in the supply of a greater amount

of available nitrogen for the fruit, and consequently an increase of concentration in the plums. This is more probable because the ratio of foliage to fruit in the Kelsey plum trees is small, particularly during years wher good crops are obtained.

TABLE XII.

COMPARISON OF CHEMICAL COMPOSITION OF KELSEY AND GAVIOTA PLUMS AT EXPORT STAGE (EXCEPT KELSEY, ORCHARD C, WHICH IS AT PRE-EXPORT STAGE) IN THE TWO SEASONS.

All results as percentages of Fresh Weight.

Orchard.	A, Kelsey.		B, Kelsey.		C, Kelsey.		C, Gaviota.	
Season.	33–34.	34–35.	33–34.	34–35.	33–34.	34–35.	33–34.	34–35.
Date of gathering.	29·1	12·2	8·2	20·2	15·2	21·2	10·1	17·1
Wt. per fruit, grams.	93	132	96	103·4	70	104·8	78·2	112·0
Dry weight .	15·40	17·83	14·89	18·20	12·78	17·24	11·73	13·72
A.I. residue .	1·83	1·78	1·56	1·82	1·86	1·93	1·88	1·78
Acidity (c.c. N/1).	13·30	9·56	13·10	8·73	17·30	15·50	19·6	18·30
Glucose . .	3·29	3·16	2·47	2·77	2·64	2·88	2·80	2·74
Fructose .	4·29	2·46	3·26	2·22	3·32	1·92	2·96	2·23
Reducing sugar	7·58	5·62	5·73	4·99	5·96	4·80	5·76	4·97
Sucrose . .	4·01	5·80	5·52	5·95	3·05	4·63	2·87	3·84
Total sugar .	11·59	11·42	11·25	10·94	9·01	9·43	8·63	8·81
Nitrogen .	·0996	0·110	·0986	·1282	·1025	·1312	·0990	·1070

*Potash.**—The potassium/nitrogen ratio remained constant in both seasons. For the Kelsey and Gaviota plums at export stage in the two seasons the values were 1·99 and 2·02, and 1·80 and 1·85 respectively. It follows that in 1934–35, when the nitrogen concentration showed a substantial increase as compared with the values for 1933–34, the potash concentration also showed a corresponding rise. It has been mentioned that high nitrogen content in fruit is deleterious to its keeping quality. On the other hand, strong evidence exists that potassium favours good keeping quality. Amongst others, Wallace (46) found that potassium-deficient plums were susceptible to internal breakdown in store, while J. Brown (10) states that good keeping quality in apples is associated with a high percentage of potash and phosphate. It is therefore possible that the effects

* All potash values were taken from Cohen (12).

of higher nitrogen concentration in the plums of the second season were offset by the favourable effects of higher potassium concentration, as it was observed that the Kelsey plums in 1935 showed better keeping quality than those of the previous season (17).

Total Solids.—The seasonal variations in total solids and sugar content of the plums were similar to those observed for nitrogen. The rates of dry-weight increase did not vary significantly in both seasons until growth of the stone was complete. The rate of increase in total solids then rose rapidly in 1934–35, and reached a maximum of 0·34 gram per day per fruit for the Kelsey plums. In 1933–34 the corresponding maximum was only 0·28 gram per day. Consequently, fruit gathered at the same stage of maturity in the two seasons showed a 20 per cent. difference in concentration of total solids in the Kelsey plums and about 10 per cent. in the Gaviota variety (Table XII).

Sugars.—The rate of accumulation of total sugars was also greater in the second season than in the first. A comparison of the maximum rates attained in both seasons illustrates this point. For the Kelsey plums these maxima were 0·22 gram and 0·14 gram per day per fruit, while for the Gaviota plums they were 0·207 gram and 0·107 gram in 1935 and 1934 respectively.

The greatest differences were observed in the relationships of the sugar fractions. In all the Kelsey samples collected in 1934–35 the fructose concentration was always lower than that of glucose, and at export stage the fructose/glucose ratio (F/G) was $0{\cdot}80 \pm {\cdot}02$. Tables IV–X show that in 1933–34 the fructose concentration of the Kelsey plums became greater than that of glucose early in the second growth phase. When gathered at export stage in 1934 the plums had a F/G ratio of $1{\cdot}30 \pm {\cdot}02$. The Gaviota plums did not show such divergence from season to season, and in 1933–34 only those from orchard C showed a F/G ratio greater than unity. The exact significance of the F/G ratio is not clear. Evans (19) observed that the F/G ratio varied slightly in different sets of the same variety of apples but showed greater fluctuations from variety to variety. He found that the ratio changes but little during storage, and suggests that it is a characteristic property of the apple depending on its metabolism. Variation in the ratio would indicate a different type of metabolism in different apples. In such a case the observed differences in the F/G ratio in Kelsey plums in the two seasons might have a bearing on the difference in keeping quality displayed by these plums in the two successive years (17).

When the plums were picked for export the total sugar concentration in both varieties did not vary significantly in the two seasons. But the plums showed considerable differences in the proportion of sucrose in the total sugar. Thus, in 1934 the total sugar in the Kelsey plums for export

contained only about 34 per cent. sucrose, but in 1935 it rose to 48–52 per cent.

Acidity.—The acid concentration was the only one which had a higher value in plums of the first season than in those of the second. The rate of acid production was somewhat slower in the second season. In the Kelsey plums it reached a maximum rate of 4·1 c.c. N/10 per fruit per day, whereas in the 1933–34 season it reached a rate of 4·5 c.c.

Chemical Composition at Commercial Picking Stage.—It is difficult to elucidate the significance of the above seasonal differences. It was observed that the Kelsey plums in 1934–35 showed less breakdown in store than those of 1933–34 (17). This applies not only to plums picked at corresponding stages of maturity but also to the crop as a whole. In the first season it was found that the more mature Kelsey plums were less susceptible to internal breakdown in cold store than the immature plums, and that the plums with better keeping quality showed in general a higher proportion of sucrose. It is therefore significant that the differences between the chemical composition of the export stage Kelsey plums of 1934–35 and the export stage Kelsey plums of 1933–34 were similar to the differences observed between the chemical composition of mature and immature Kelsey plums of the 1933–34 season (Tables IV–VII and XII). In other words, Kelsey plums when picked for export in 1935 were physiologically in a more advanced stage of maturity than those of 1934. This is confirmed by the following observations. When the fruit was picked for export in 1935 growth increase (as measured by increase in weight) was at a minimum, acidity formation had stopped, and both the amount of acid per fruit and the rate of dry-weight accumulation were falling rapidly. In 1934, however, the plums were picked when they were still increasing in weight, although at a decreasing rate, total solids were still accumulating at a maximum rate, and the acid content of the plums was also at its maximum.

It must be mentioned, however, that the Kelsey plums picked in 1934 showed a minimum rate of intake of nitrogen and a falling rate of accumulation of total sugar, while in 1935 sugar intake was at its maximum rate at picking time and nitrogen intake was still considerable, albeit at a decreasing rate. It is therefore possible that nitrogen might have been a limiting factor in the 1933–34 season, as it has already been shown that nitrogen and sugars accumulated in the fruit as long as it remained on the tree. Furthermore, Long Ashton investigations indicate that plums as a class yield the best results under "high" nitrogen conditions (46, 7).

Wallace (45) has indicated that nitrogen deficiency strongly affects the total sugar content and, if the fruit is a variety with colour, it intensifies that colour. Gourley and Hopkins (22) similarly observed that apple trees

heavily treated with nitrogen gave fruits which showed a high nitrogen content and displayed less, and much delayed, coloration compared with those from non-fertilised trees. It is perhaps possible that similar conditions obtain in the plum. This would explain why plums with the same amount of colour might actually not be in the same physiological stage of maturity. As the grower judges picking-maturity by appearance of colour in the plums, it would then be necessary to modify the usual practice in years of heavy crops. In such seasons fruit should be picked with much more colour than the usually accepted standard for Kelsey plums. Another practical possibility is to "thin" heavily and to apportion carefully the amount of fruit to leaf area.* That alteration of accepted standards for picking-maturity from season to season is a tenable proposition in practice has been shown in Canada (40), where it was found that to avoid large losses due to Jonathan breakdown, it is essential when judging picking-maturity to take into consideration the magnitude of the crop per tree and similar seasonal variations.

Comparison of Properties of Plums from Various Localities.—In Part I a detailed analysis was given of the differences in environmental and climatic conditions of the three farms from which fruit was taken for this investigation. It was then pointed out that there is a lack of uniformity as regards the age of the trees and the stock on which they are grown. Nutritional treatments on the three farms also varied. No attempt can therefore be made to interpret the composition of the plums, or rates of growth of the fruit, in terms of effects brought about by either cultural or climatic factors. Evidence over a longer period and from a larger number of orchards is needed before such effects can be traced.

The data at the writer's disposal does not indicate any marked differences in the plums from farm to farm. In general, the Kelsey plums from orchard C were of smaller size than those from either orchard A or B. The observed differences in tree characteristics might account for this, as Gaviota plums from orchard C, which are grown on fine upstanding trees, were in both seasons superior in size to those from orchard A or B.

In the 1933–34 season the Kelsey plums from orchards A and B showed a 10 per cent. higher concentration of dry weight and total sugar than the plums from orchard C. In the 1934–35 season these conditions were reversed. Only in the second season did nitrogen concentration differ materially in the plums of the various orchards. Plums from orchards B and C showed a 20 per cent. higher nitrogen content than plums from orchard A.

* Winkler (49) reports that thinning vines to obtain increased leaf area per cluster of grapes resulted in the production of larger berries and better quality. Magness (36, 37) observed that size and quality of apples are almost entirely determined by leaf area.

The Kelsey plums in orchard C showed a higher acid content in both seasons than plums from either orchard A or B.

The curves for growth and changes in sugar and acid were similar for all orchards. The duration of the growth period was almost the same for all orchards, except that the plums set earlier in orchard A than in B or C. Fruit in orchard A was consequently gathered at an earlier date.

The rate of growth (as measured by increase in weight of constituents per fruit) was lowest in orchard C. Here the internal factors of the trees no doubt play an important rôle.

It therefore seems that seasonal variations have a more marked effect on the concentration of the organic constituents in the plum than environment. Cohen (12) finds that the direct opposite holds for potash and phosphate. The effect of soil apparently predominates in this connection, for Cohen found that a high available potash and phosphate content of soil resulted in a high content of these elements in the plums.

From the grower's point of view, the most vital test of the importance of environmental conditions on growth is the effect such conditions have on the keeping quality of the fruit. Actual storage tests conducted on the plums show that for the three farms concerned environmental effects are negligible when compared either with effects brought about by differences in maturity of the plums on picking, or by seasonal variations (15, 17).

Summary and Conclusion.

Part I. Materials and Methods.—A description is given of the chemical changes in Kelsey and Gaviota plums during growth in the two seasons 1933–34 and 1934–35. The fruit was collected from orchards in three different localities in order to trace effects due to environment. The essential differences in the orchard characters are described.

The constituents estimated were dry weight, alcohol insoluble residue, nitrogen, acid, and sugars. The method of preparing samples for analysis is described and methods of analysis are briefly discussed. It was found that it is essential to decolorise the sugar extracts when estimating reducing sugars by the Fehling's method. The method of Lane and Eynon was adapted for estimating small quantities of sugars.

A comparison is given of acid and sugar analyses made on juice and on alcohol extracts of the plum. Good agreement between the two sets of analyses was obtained, but it was found that the sucrose content determined in alcohol extracts was consistently lower than when determined in the juice. This was traced to a partial hydrolysis of sucrose in the alcohol extracts.

Part II. Changes during Growth.—The life of the plum on the tree may

be divided into three stages. During the first stage the growth of the stone predominates over that of the flesh. The rate of growth and of increase in all constituents of the flesh (except alcohol insoluble residue) is comparatively slow. The concentration of total solids, alcohol insoluble residue, and nitrogen falls rapidly during this period, but the acid concentration remains high. Starch is present in the plum at the beginning of this stage only, and for but a short period.

The second stage of growth commences when the stone is fully developed. It is characterised by a rapid rise in the rate of growth of the plum and in the rates of increase of total solids, sucrose, nitrogen, and acid per fruit. These rates of increase finally reached a maximum value at the end of this stage.

The third stage of growth is a period of maturation. The rate of accumulation of constituents per plum falls rapidly. The fruit softens, acquires colour, and finally becomes fully ripe. It was observed that sucrose and nitrogen accumulate in the flesh as long as the plum remains on the tree.

The relationship between the various constituents is discussed, and it is suggested that organic acids and alcohol insoluble residue have a common origin. Starch appears to be formed alternatively to acids. It was found that nitrogen intake is related to growth, and that a high rate of growth is accompanied by a high rate of acid formation. It is indicated that the metabolic changes in the plum during growth are reflected in the changes of the sugar fractions.

The nature of the chemical changes in Kelsey plums is essentially the same as in Gaviota plums, except that the rate of growth and the rate of accumulation are greater in the latter variety.

The rates of increase of constituents was much higher in the second season than in the first. This is ascribed to the poorer crops borne by the plum trees in 1934–35. The plums in this second season showed at commercial picking time a higher nitrogen, dry weight, and sucrose content, and a lower acid content than plums at the same stage of maturity in 1933–34. They also showed better keeping quality in cold store.

It was found that the composition of the plums was affected more by seasonal variations than by differences in environment.

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Chemistry Department,
University of Capetown,
September 1935.

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NEW GOBIOID AND CYPRINID FISHES FROM SOUTH AFRICA.*

By J. L. B. Smith.

(With Plates III–V and three Text-figures.)

(Read October 16, 1935.)

Family Gobiidae.

Gobius vonbondei n. sp.

(Text-fig. 1 and Plates III and V, fig. A.)

Body fairly compressed, markedly so posteriorly. Dorsal profile even, moderately sloping before eyes, snout blunt, rounded.

Depth equal to length of head, 3·5 in length of body. Eye 4·3, interorbital 4·0, snout 3·3, and postorbital part of head 2·0 in length of head. Least depth of preorbital 1·8 in eye.

No barbels. Series of papillae on cheeks; below the eye a row with short vertical transverse series. A series along the lower margin of the preorbital extending beyond angle of mouth on to preopercle. A single series in a shallow groove along the lower surface of each mandible. Nostrils small, posterior circular, anterior with plain flap. A large pore above the anterior nostril.

Mouth moderate, slightly oblique, jaws equal, maxilla extends to below anterior margin of pupil. Teeth in 3–4 rows in each jaw, with an outer enlarged series of 14–15, caniniform. An outwardly flaring curved canine tooth on each side of lower jaw. Palate and tongue edentate. Tongue anteriorly truncated, adnate. A papillose cutaneous process across roof of mouth.

Gill-opening restricted, membranes broadly fused with isthmus from below posterior half of operculum. 5 gill-rakers on lower margin of anterior arch, of curious claw-like design. The upper limbs of the anterior two arches have a forward extension bearing three large claw-like processes, which have below numerous shorter papilliform processes.

D VI + I, 14. First dorsal originates just behind pectoral base, twice as far from caudal base as snout tip. Spines elongate, filamentous, 1st 1·4,

* The Council desires to acknowledge the receipt of a grant from the Carnegie Corporation through the Research Grant Board towards the cost of printing this paper.

2nd 1·2, 3rd 1·0, 4th 0·85, 5th 1·3, and 6th 2·1 in length of head. Base of first dorsal 1·4 in head. Membrane from 6th spine reaches origin of second dorsal. Second dorsal inserted slightly nearer caudal base than snout tip, above the 20th lateral scale, spine 2·2 in head, anterior rays 2·0 in head, increase to the 7th (longest) 1·5 in head, thereafter graduated shorter. Base of second dorsal 1·2 times head. Hind margin of fin does not reach the caudal.

A I, 12. Originates below the origin of the second dorsal. Spine 1·5 times eye; first ray, shortest, 1·7 in head; penultimate, longest, 1·3 in head. When laid back the hind margin of the fin reaches on to the caudal fin. Base of anal equal to that of second dorsal.

Pectoral rounded, of 17 rays, 1·1 in head, tip reaches below origin of second dorsal.

Ventrals united, as long as pectorals.

Caudal broadly rounded, of 15 principal rays. Peduncle about as long as deep.

Scales moderate, mostly ctenoid (Plate III, A), but those on the nape, head, pectoral base, and chest, cycloid. Lat. ser. 52, l.tr. 18, predorsal 23, which end above posterior third of eye. Scales in advance of pectoral base smaller than posterior scales. About ten series of scales across upper portion of opercle, rest of head (except dorsally to interorbital) naked.

Colour.—Brownish, slightly lighter below. Five dark cross-bars, narrower than eye, much narrower than interspaces; first below middle of first dorsal, second below anterior dorsal rays, third below middle dorsal rays, fourth below posterior dorsal rays, last across peduncle. Between each pair a narrower faint stripe. Faint stripes below origin of first dorsal, over nape, and behind eye. Opercle dark below. A faint dark smudge below anterior margin of eye. A large black spot at upper margin of opercle above pectoral base, another similar on upper side of caudal base (ocelli in life?); three small dark spots along base of dorsal; a similar spot on upper part of hind margin of caudal, and four spots along lower margin of caudal. Dorsal, anal, and ventrals dusky, other fins light.

Length.—133 mm.

Locality.—Natal.

Type (♂) in the Albany Museum.

Named after Dr. C. von Bonde, Director of the South African Government Fisheries Survey, who has donated numerous valuable specimens to the Albany Museum.

The type is a ripe male. Conspecific is also a smaller ripe female, 120 mm. total length. A certain amount of sexual dimorphism is exhibited by this species. The body of the female tapers to the peduncle slightly more than that of the male, while there are only the two large spots, one

at the pectoral the other at the caudal base, the smaller spots on the dorsal and caudal being absent. Chiefly the sexes differ in the nature of the dorsal fins. The first dorsal is longer based, but not as high in the female, while in the second dorsal, the posterior rays of that of the female are the longest, the shape of the fin resembling that of the anal. Also the ventral is slightly shorter, scarcely reaching the vent.

D VI + I, 14, A I, 13; lat. ser. 53, l.tr. 19; predorsal 23. 6 gill-rakers.

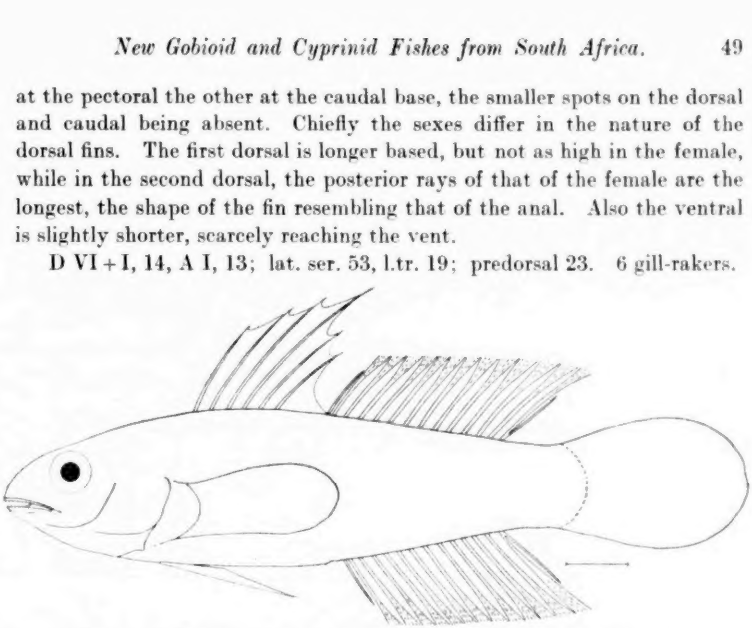


FIG. 1.—*Gobius vonbondei* n. sp. (Female). The line represents 1 cm.

G. vonbondei is easily distinguished from all other South African species by the high dorsal fin, as well as by numerous other features.

Gobius gulosus n. sp.

(Text-fig. 2.)

Body fairly slender, sub-cylindrical, compressed posteriorly. Dorsal profile even, with slight concavity before eyes. Snout moderately sharp.

Depth 5·0, length of head 3·1 in length of body. Eye 5·4, snout 3·0, interorbital 6·0, and postorbital 2·1 in length of head. Least depth of preorbital equal to eye.

No barbels. 6–7 undulating series of papillae on cheeks. Various other series; along preopercle margin, double, behind eye to occiput, and along head above upper margins of opercle and preopercle. A series along each lower margin of opercle, with a third forming a triangle. A deep groove containing papillae on each side of snout before eye. Several pores on snout. Chin and lower surface of rami of lower jaw with papillae. Anterior nostril tubular.

Head very depressed, maximum width behind eyes 1·2 in length, considerably wider than deep. Mouth large, oblique, lower jaw projects

slightly. Maxilla extends below anterior border of orbit. Slender conical teeth in 4–5 rows in each jaw, outer series but slightly enlarged. Tongue adnate, truncated. Cutaneous process in roof of mouth narrow. Gill-opening restricted, membranes fused with isthmus from below middle of opercle. 9 gill-rakers on lower limb of anterior arch, fairly short, moderately stout.

D VI + I, 8. First dorsal originates 1·8 times further from caudal base than snout tip, above the 5th lateral scale. Spines slender, 1st 3·0, 2nd 2·2, 3rd (longest) 1·9, 6th 4·0 in length of head. Base of first dorsal 1·9 in head. Two dorsals close together. Second dorsal originates slightly nearer caudal base than snout tip, above the 13th lateral scale. 1st ray 2·0 in head,

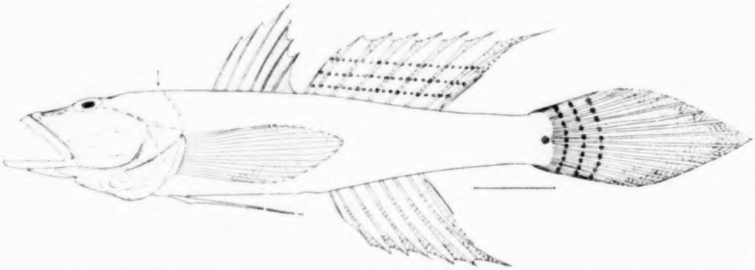


FIG. 2.—*Gobius gulosus* n. sp. The small arrow indicates anterior limit of scaling. The line represents 1 cm.

increase to penultimate (longest) almost as long as head, when laid back reaches well on to the caudal fin. Base of 2nd dorsal 1·4 in length of head.

A I, 7. Inserted below the 2nd dorsal ray, below the 15th lateral scale. Spine short, first ray 2·2, remainder increase to penultimate, longest, 1·2 in head, depressed reaches to caudal base. Base of anal 1·8 in head.

Pectoral more or less lanceolate, of 16 rays, as long as head, tip reaches beyond anal origin, to 16th lateral scale. No free rays.

Ventrals 1·4 in head, reach to vent, basal membrane wide.

Caudal lanceolate, 1·2 times head; peduncle slender, almost 2·5 times as long as deep.

Scales moderate, mostly ctenoid, but cycloid on the nape, on the chest, on ventral surface of body, on pectoral base, and on caudal base. Lat. ser. 31, l.tr. (between dorsal and anal) 8, predorsal 8–9, very small. Posterior scales of body much larger than those anterior to dorsal origin. Head entirely naked except few predorsal scales, which extend almost above hind preopercle margin. Chest only lightly scaled.

Colour.—Uniform dark olive, nape darker, slightly lighter on belly. First dorsal with large dusky blotch over last three spines. Several rows

of dusky spots along base of second dorsal: also over base of caudal. Ventrals dusky. Pectorals light.

Length.—91 mm.

Locality.—Bushman's River, Alicedale (Cape Province, about 30 miles from nearest point of coast).

Type in the Albany Museum.

A single specimen, presented by A. Cruden, Esq.

This species would appear to fall into *Stenogobius* Bleeker, of which somewhat doubtful sub-genus no representative has hitherto been recorded from South Africa.

G. gulosus is well differentiated from all other species from South Africa by various features. It is closest to the widely distributed species *giuris* Ham. Buch., but is distinguished chiefly by the elongated fins, by the absence of scales from the occiput, by the arrangement of the buccal papillae, and by the adnate tongue, besides other features. It is not even unlikely that *gulosus* has originated, by isolation, from *giuris*, or that both species have developed from a common ancestor.

Extensive collecting in the fresh waters of the Eastern Province of South Africa will almost certainly result in the discovery of numerous new species of fishes, some of which at least will not improbably show relationship to, or even traces of origin from, known widely distributed forms. In that area it would appear that geographical and climatic changes have considerably affected the character of the larger rivers. Even those which at one time were presumably of continuous flow, and with few barriers to hinder the inland penetration of marine species, now have the inland freshwater without direct or continuous communication with the sea. Only during floods is there continuous water, but at those times the current is too swift to allow of counter migration. Actually the periodic inundations which occur in that region take heavy toll of the fish life of the fresh waters, for after any heavy spate innumerable dead fresh water fishes are thrown up on the shore in the neighbourhood of the mouth of any large river in the Eastern Province area.

The Bushman's River is tidal for over 20 miles, but beyond that consists at normal times of merely a series of disconnected pools. The course of the river from Alicedale to the sea would be at least 50 miles. Any upward migration in that river would appear impossible, and *gulosus* is most probably a localised fresh water species.

Family ELEOTRIDAE.

Eleotris limosus n. sp.

(Plates IV and V, fig. B.)

Body robust, moderately compressed, maximum width at shoulder 1·2 in depth. Dorsal profile flat, with deep concavity before eyes.

Depth 4·1, length of head 3·3 in length of body, Head 1·2 times wider than deep. Eye 6·5, interorbital 2·4, snout (measured obliquely to tip) 3·4, and postorbital part of head 1·6 in length of head. Least depth of preorbital 1·8 in eye. (Length of head measured obliquely to snout tip.)

Anterior nostril tubular, apically dilated, immediately above maxilla; posterior before the orbit. A large pore close above the anterior nostril. Several papillose, muciferous canals on cheek, two radiating down from the eye; from the anterior nostril along the lower preorbital margin another, which extends beyond the angle of the mouth well on to the preopercle. A groove behind the eye extends to the upper margin of the gill-opening; at the origin next the eye is a large pore; also several others in and above the course of the groove.

Anal papilla broad and flat, about as long as eye.

Gill-opening fairly wide, gill-membranes not united, but fused narrowly below with isthmus. Gill-rakers 12, anterior moderate, stout, posterior mere knobs. Pseudobranchiae well developed. Space between rami of lower jaw wide, transversely rugose. 12–14 apically dilated papillae in a series in a groove along each side of the lower surface of the lower jaw, separated by a small space from a posterior groove containing two similar papillae and ending in a large pore.

Mouth large, oblique, lower jaw projects strongly, maxilla extends to almost below centre of eye. Uniform minute conical villiform teeth in each jaw in a band, anteriorly half as wide as eye: no canines, no enlarged outer series. Palate and tongue edentate. Tongue free, wide, rounded.

D VI + I 8. First dorsal inserted midway between the tip of the snout and the hind margin of the base of the second dorsal, above the 6th lateral scale. Base of first dorsal 2 in head. 1st and 6th dorsal spines shortest, 3rd 2·3, 5th 2·4 in length of head, 1·8 in depth of body. Second dorsal very close to first, separated by a space about 3 in eye. Second dorsal originates above the 17th lateral scale, slightly nearer caudal base than hind margin of eye. First ray (shortest) 2·0, last ray (longest) 1·15 in head, tip of depressed fin reaches well beyond caudal base. Base of second dorsal 1·7 in head.

Anal I, 7. Inserted below the 19th lateral scale, below the base of the second dorsal ray, midway between the caudal base and hind preopercle

edge. Base of anal 2 in head. 1st ray (shortest) 2·5, last (longest) 1·5 in length of head. The depressed last ray reaches the caudal base.

P 14. 1·1 in head, rounded, with heavy base, tip reaches to below the base of the first dorsal ray, to the 19th lateral scale.

Ventrals inserted below pectorals, 1·4 in head, tip reaches just beyond vent, apex of longest ray slightly filamentous.

Caudal 15, large, rounded lanceolate, just longer than the head (base obscured by scales). Peduncle 1·5 times as long as deep.

Scales large, mostly ctenoid (Plate III, B), but the predorsal scales and those on the head, on the pectoral base and on the chest, cycloid. Lateral rows 41 to caudal base, several smaller scales beyond: l.tr. 13 (dorsal to anal); 12 vertical series on preopercle, 5 on opercle, 18 predorsal. Whole body and head scaly, except muzzle, lower margin of lower jaw and front half of cheek, naked. Caudal scaly basally, other fins not.

Colour.—Uniform dark olive, muzzle slightly darker. Fins dusky; first dorsal with a few basal dark spots, second dorsal and caudal with rows of numerous dark spots. Second dorsal, caudal, anal, and ventral with very narrow light margin (in life faint orange).

Length.—270 mm.

Locality.—Isipingo lagoon, near the sea.

Type in the Albany Museum.

E. limosus is closely related to *ophiocephalus* C. and V. and to *madagascariensis* C. and V., which are indeed only doubtfully distinct one from the other, agreeing closely in all features except that the latter species has a more elongate caudal peduncle and an extra ray in the second dorsal (*fide* Boulenger, F.W.F., Africa, 1916, vol. iv, pp. 15–16). *E. limosus* is differentiated by several features, notably by the greater size of the fins, while the two dorsals are much closer than in *ophiocephalus* and in *madagascariensis*. Further, the teeth of *limosus* are of uniform size, there being no even slightly enlarged outer series. Day (Fishes of India, 1888, p. 312, pl. lxvii, fig. 2) described and figured *ophiocephalus* C. and V., and Boulenger (*loc. cit.*) has accepted his diagnosis, whereas Day's specimens cannot possibly be conspecific with those described by Boulenger. Day stated that his specimens had 31–34 scales, whereas Boulenger gave 35–42. It may be noted that Day's figure agrees in very few significant features with his description, the discrepancies being so marked as almost to appear as if some confusion of specimens had occurred. At all events, either the specimens described by Day were not *ophiocephalus* C. and V., or, if they were that species, then Boulenger's were not. Actually Boulenger's description (*loc. cit.*, p. 15) agrees very well with my specimen, and it is not unlikely that his specimens will be found conspecific with *limosus*.

In view of the habits of the ELEOTRIDAE it would be surprising to find our southern African species identical with those from India.

Family CYPRINIDAE.

Barbus senticeps n. sp.

(Text-fig. 3.)

Body moderately compressed. Depth equal to length of head, 3·4 in length of body. Eye 5·0, snout 3·7, interorbital 3·0, and postorbital 1·8 in length of head.

Snout somewhat blunt and swollen, with sharp concavity, part of a transverse groove, before eyes. Upper surface of snout and head with

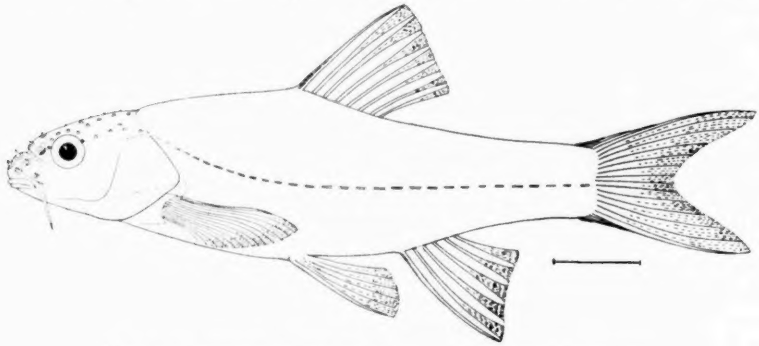


FIG. 3.—*Barbus senticeps* n. sp. (Type). The line represents 1 cm.

numerous spiny tubercles, each with a rounded enlarged horny base; those on the snout large, behind the eyes much smaller. A single barbel on each side, 1·5 times eye.

Mouth inferior, lower jaw included, maxilla extends to below nostrils. 7 gill-rakers on anterior arch.

D III, 7. Inserted slightly nearer snout tip than caudal base. Anterior rays 1·3, posterior 2·5 in head. Edge of fin straight.

A III 5. Inserted twice as far from snout tip as caudal base. Anterior rays 1·3, posterior 2·5 in head. Edge of fin gently concave. Pectorals 1·3 in head, reach to ventral base. Ventrals inserted very slightly in advance of dorsal, 1·4 in head, reach to anal origin. Caudal deeply forked, peduncle 1·8 times as long as deep.

Scales large, with a moderate number of widely radiating striae. l.l. 30, l.tr. 8 (dorsal origin back): 3 between ventrals and lateral line, 10 around peduncle, 14 predorsal.

Colour.—Dark olive-brown above, lighter below. An obscure dark lateral stripe. Tubercles reddish.

Length.—77 mm.

Locality.—Kromme River, Assegai Bosch (near Humansdorp, C. P.).

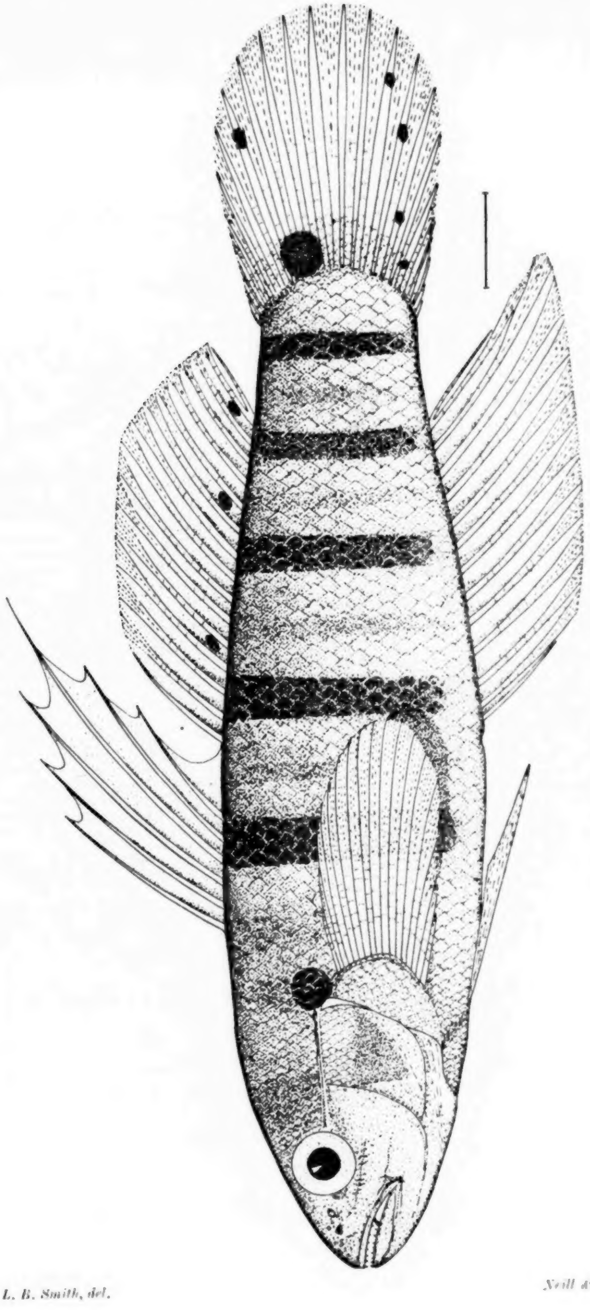
Type in the Albany Museum.

This species falls into the small group which have the dorsal spine simple and flexible, and only one barbel. It is near to *anoplus* Weber and to *afer* Peters, but differs in the much smaller eye, in the much longer barbel, more anterior insertion of the dorsal, fewer scales transversely, and several other features.

Numerous new species of this genus doubtless await discovery in the Eastern Province, since the fresh water fauna of that region has not been seriously investigated.

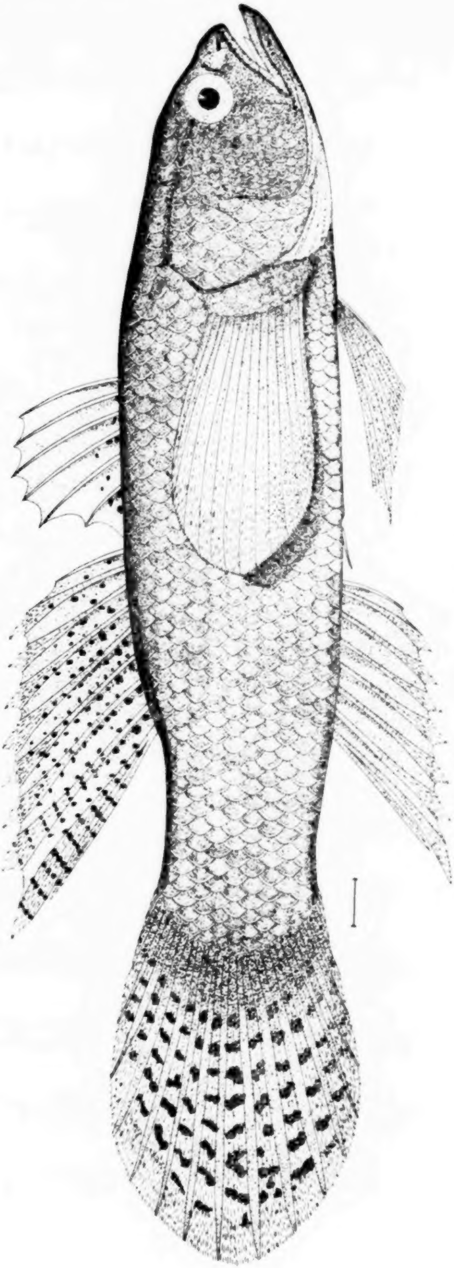
I wish to express my gratitude to the Research Grant Board of South Africa (Carnegie Fund) for financial assistance.

Albany Museum,
Grahamstown,
September 1935.



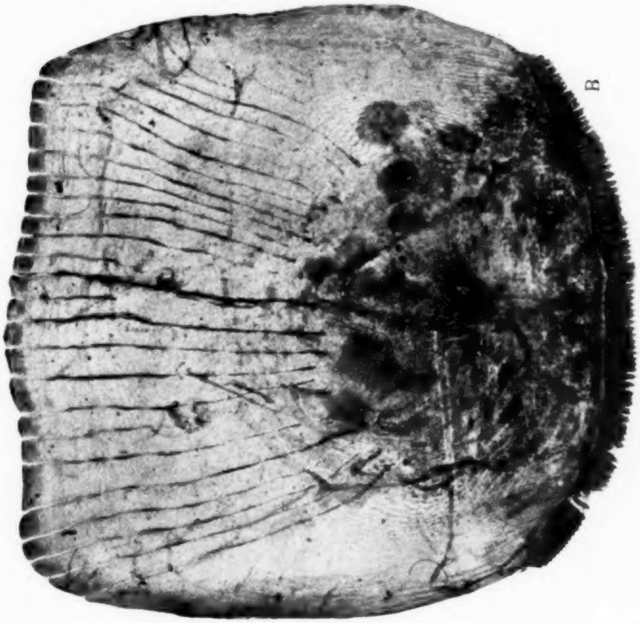
Gobius rouboudei n. sp. (Male) Type. The line represents 1 cm.

J. L. B. Smith, del. *Neill & Co., Ltd*

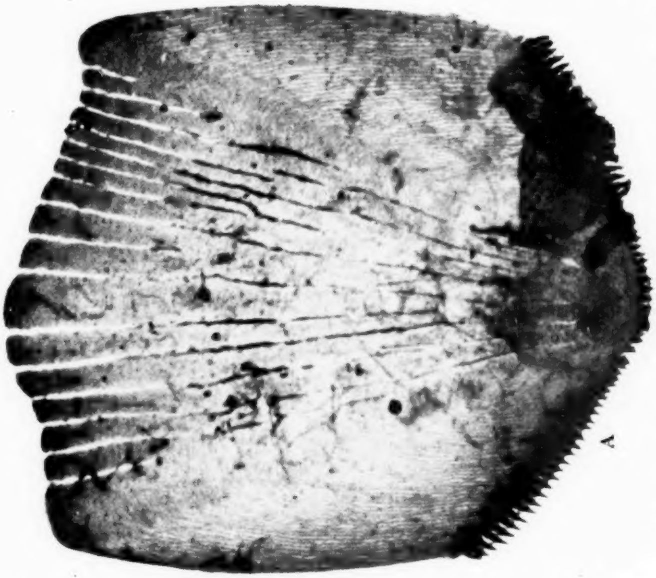


Eleotris limosus n. sp. (Type). The line represents 1 cm.

J. L. B. Smith, del. Neill & Co., Ltd.



B



A

A. 12th medio-lateral scale of *Gobius conbandi* n. sp. ×34. B. Similar scale of *Eleotris limosus* n. sp. ×12.

Each from the Type.

J. L. B. Smith. Neill & Co., Ltd

PRESIDENTIAL ADDRESS.

THE SURFACE GEOLOGY OF THE KALAHARI.

By A. W. Rogers.

(With a Sketch Map.)

(Read March 18, 1936.)

When Dr. Passarge wrote his careful description of the Kalahari over thirty years ago he divided the deposits resting on a floor of Karroo and older rocks into the Botletle beds, Kalahari limestone, Kalahari sand, "Decksand" and Alluvial Deposits, treating them as a stratigraphical succession (1); subsequent work has shown that this scheme cannot be maintained, because the characteristics of the Botletle beds and Kalahari limestone are not confined to the older deposits; in fact they are almost certainly in course of production to-day.

Mr. Maufe's grouping of the beds as a Kalahari System and recent alluvial deposits (2) satisfies our present knowledge of the country between the Zambezi and Orange Rivers, though the Kalahari region must be considered to stretch farther north, east, and west than those limits imply, while some deposits in Bushmanland should be included in the System, which may be looked upon as a younger analogue of the Karroo System, though much less thick and less extensive. I will not discuss at length whether the Kalahari System should survive as one of the great stratigraphical groups of South Africa and include contemporaneous marine deposits near the coast, but there seems no good reason why it should not. Just as the Karroo System includes some Palaeozoic as well as Mesozoic rocks, so the Kalahari System may include some Mesozoic as well as Tertiary and later rocks. There is obvious difficulty in correlating terrestrial and marine deposits, so we cannot be surprised at existing differences of opinion as to the limit between Carboniferous and Permian beds, for instance, in South Africa, or the almost complete ignorance about the limits between later Systems in the interior of the continent, because those Systems are based on marine faunas.

That the rocks of the Kalahari System in the type region lie unconformably upon a floor made of various rocks ranging in age from the

Archaean to the lavas belonging to the youngest part of the Karroo System, as developed in South Africa, is known from many observations round its present edge and from the fewer recorded from within the region. No Cretaceous rocks are known to take part in the floor, but the dinosaur bones from a well in Bushmanland indicate that the Kalahari deposits began to accumulate in Cretaceous times (3). We thus have a period ranging probably from the lower Jurassic to some date in the Cretaceous during which denudation prevailed over the Kalahari region and partly removed the Karroo sediments and volcanic rocks from it. Estimates of the thickness of Karroo beds removed from the upthrow side of the Wankie fault range from 500 to over 2000 feet (4); the Kalahari floor passes evenly across that fault, so these figures give us a notion of the extent of denudation that took place in the Kalahari after the Karroo lavas were emitted and before the Kalahari beds began to accumulate.

The Kalahari floor was not so flat as the present surface, except the valleys of some of the rivers, for in places deposits over 400 feet thick have been laid down on it, and the hills, rising above the sand-veld, must have lost height through weathering during the very long period involved. The position of the Kalahari floor as regards sea-level when the deposits began to accumulate cannot yet be stated. We may suspect that the great tract of Karroo lavas and sediments covering South Africa in early Jurassic times did not lie very far above that level, and that on it the main lines of the present drainage were established. So far as we can yet see, the thick volcanic group in Basutoland was the only part of the Stormberg volcanic series that formed a great watershed; the still thicker volcanic group of the Lebombo is inclined eastwards and is trenched by apparently consequent rivers flowing east, while the Cretaceous beds of Zululand rest unconformably against it and dip at low angles off its flank. In South-West Africa large remnants of Karroo sediments and volcanic rocks extend to sea-level in the Kaokoveld, though neither Cretaceous nor Tertiary beds have been recorded near them; so both in the east and west, within the latitudes of the Kalahari, there is a marked flexure of the continental surface which, in the east at least, was far advanced in Aptian times. There is evidence pointing to the presence of much volcanic rock in the middle Kalahari region between the Zambezi and the Molopo, and it may have been important in forming the watershed between the Zambezi and the Limpopo on the north and the northern tributaries of the Orange River to the south (5).

At present it is permissible to think that in middle and late Jurassic times the Orange drainage was established and that the Karroo volcanic rocks and sediments were being washed away westwards, but the existing high gradient of the Orange River does not allow us to accept any such

great antiquity for the present high average level of the catchment (6). The thousand feet deep trough of the Orange valley through the granites and metamorphic rocks from the Oograbies Falls to within 30 miles of the Atlantic is not a feature of recent date: it must have been cut gradually upstream from the mouth during long ages, while the subcontinent as a whole rose in altitude. The Hygap receives, or has received, the drainage of a large area (over 80,000 miles) of the Kalahari brought down by the Molopo, Auob, and Nossob, while the region far to the north is drained or traversed by the Zambezi; between the two catchments, in the north-west, lies the Okavango, terminating now in the Makarikari depression, which is reached by the Botletle through a gap in the rising ground fronting the Okavango delta. At the south-west end of the rising ground Ngami lies behind it, and at the north-east end the Mababe depression, 20 feet below the confluence of the Linyanti and Zambezi (6a), is in a similar position; the Okavango and the Zambezi are separated by the Linyanti, but in some years the Okavango contributes water to the Linyanti and Zambezi through the Selinda spillway, as du Toit calls it. That local earth-movements of late date have been the cause of the peculiar state of the Okavango drainage by raising the ground across it cannot be doubted; but whether its connection with the Zambezi was partly interrupted, or whether a suspected former flow south-eastwards to the Limpopo was merely interfered with by the bar of rising ground, and the delta originated in spite of the Botletle channel being maintained across the rising ground, while its progress to the Limpopo was finally stopped by another belt of raised country east of what became the Makarikari depression, is a question to which our present knowledge of the distribution of the fossil and living mollusca does not give a certain answer.

It was suggested by Professor Schwarz (7) that the Orange River used to receive water from the Zambezi, Linyanti, and Okavango, but the difference between the fossil shells in the two river systems negatives the connection: the limestones in the valleys of the northern rivers contain conspicuous species of *Ampullaria*, *Lanistes*, *Melania*, and *Viviparus* which have not been found in the Orange or Molopo limestones, though the latter are the much better known, nor have they been found in the limestones of the Okwa River, the Ghanzi district, or between the Okwa and Molopolole, where shells like those of the Molopo were obtained. There is also an apparently similar but less marked distinction between the mollusca of the northern rivers and those of the Limpopo region; how far this is due to want of information is uncertain, but the present evidence does not support a former continuity of the Okavango with the Limpopo; former confluence of the Okavango and Zambezi seems much more likely.

A great contrast between the northern tributaries of the Orange River

from the Kalahari and the eastern headwaters is in their relative altitudes; the eastern catchment lies amongst the little disturbed Stormberg beds rising over 10,000 feet above the sea, while the Kalahari catchment rises to about half that height; the eastern catchment is deeply dissected, while the Kalahari is a plain in part made of the same rocks as the eastern catchment but covered by scores or a few hundred feet of Kalahari deposits. There may have been a difference in altitude at the close of the volcanic period, but subsequent uplift seems to have been greater in the east, where the original thickness of the Karroo formation was greater (8).

The evidence of post-Karroo earth-movements in the Kalahari region is given most obviously by the Wankie fault, along which the country to the north-west remained at a lower level than that to the south, though the persistence of the Zambezi across it proves that the uplift took place gradually and did not divert the river into the Orange Catchment, and the Kalahari floor passes evenly across the fault. That the Zambezi cut the Batoka gorge gradually upstream is proved by the observations of Lamplugh on the progressive lengthening of the ravines in the tributaries downstream and the increasing angle of slope of the sides of the gorge in the same direction (9). The watershed in Rhodesia between the streams going north-west to the Zambezi and those going south-east to the Limpopo has a remarkably straight course trending south-west into the Protectorate. Maufe has shown that the Karroo beds on either side dip away from the divide, so that the watershed is probably due to post-Karroo warping of the surface (10). Dr. du Toit introduces another low anticlinal axis of post-Karroo date running from the Witwatersrand past Vryburg south-westwards to Buchuberg, Kenhardt, and Garies, but on other grounds than observed dips of the Karroo beds (11). The more recent post-Karroo movement proved by the levels in the Zambezi-Tamalakane country observed during the Kalahari Reconnaissance under du Toit in 1925 seems to be based on as good evidence as the Wankie fault, though the former is very much later in date and of much smaller vertical extent.

Deposits found on the Kalahari floor range from coarse gravels to marls, mudstones, and diatom earths, with various replacements and deposits of carbonates and silica brought about by the lack of easy drainage for ground water; corresponding deposits of iron oxides are much less frequent and are less conspicuous than in the south-west of the Cape Province.

Conglomerates.—The conglomerates or gravels of the Kalahari System are most extensively developed in the west, where the Weissrand, an escarpment formed by the eroded edge of the Urinanib Plateau, affords natural exposures of the sandy limestones and gravelly limestones for some 200 miles or more, while bore-holes east of the escarpment prove thicknesses

of Kalahari beds up to 300 feet (Ventershoop, quoted by Frommurze), and of conglomerates up to 154 feet (quoted by Range from N.E. Zwartfontein). No fossils have been mentioned from these deposits, but it seems very unlikely that none exist in them (12).

In the lower part of the Molopo (Hygap) there are at least 20 feet of conglomerate from 20–30 feet above the bed, and many of the boulders have come from the Dwyka tillite of the neighbourhood, and lower down the river remains of terraces lie very much higher above the bed (13). In the Mafeking district gravels lie 200 feet above the Molopo (13a).

Though the Kaap Plateau is not in the Kalahari to-day, it may be part of the Kalahari floor, for it was cut in post-Karro times (14). Some gravels on its surface contain pebbles from Pniel lavas and from Karroo beds which are not known to exist in positions from which the pebbles could have been derived (15).

The limestones and silcretes in the Kuruman, Mashowing, and Molopo valleys often have pebbles near their base. In the Kalahari north of the Molopo pebbly layers in the limestones have been recorded, but they have not been found so generally as in the Urinanib Plateau or in the Molopo. Curious rounded boulders of conglomerate with pebbles up to an inch across set in a white, hard clay matrix without carbonates were thrown from a well 40 feet deep in the valley about 30 miles N.W. of Molopolole where there are low cliffs of silcrete; the pebbles are chiefly of quartz, agate, quartzite, red felsite, and granite, while staurolite, kyanite, and garnet occur as grains of sand. . No beds of conglomerate from which these boulders could have come are known, but the rock looks more like a Kalahari rock than one of earlier date.

Sand.—Sand is the predominant material seen throughout the region. South of the Molopo it is red, as it also is along the eastern border near the railway and in the Zambezi valley, but on the route from Molopolole to Ghanzi it is generally pale yellowish or brownish below the surface and grey on top. In the Ghanzi district streaks of pink and red sand appear, becoming general westwards towards Gobabis, and it is more gritty in that direction, fragments a quarter of an inch across being often seen. Northwards from Ghanzi to the Kopjes greyish sand prevails. The surface of the sand-veld is undulating on the route from Molopolole to Ghanzi; accumulations that can be called dunes are seen on the southern side of pans and near the Okwa River; the undulations or bults have their greater lengths in a general N.E. or E.N.E. direction in this region, and east of Audji Macgregor records N.N.E. dunes (16). South of the Molopo and Kuruman Rivers the sand is in the form of dunes over large areas, though they are well covered with grass and bush; they trend N.W. or between

W.N.W. and N.N.W. Only near the river channels and at Witsands is there much sand without vegetation, and the sand there is white.

The sand is rather fine grained, but the amount of dusty material and clay which remains long in suspension in water is very slight. In twelve samples graded by sieving the percentage of grains a millimetre or more in diameter ranges up to 1·1 by weight, and that of grains between 0·15 and 0·4 mm. ranged from 49 to 88 (17).

The grains are chiefly quartz; felspars can be found in every sample taken, but they form a very small percentage; of the heavy minerals ilmenite, tourmaline, and zircon are always found. In a series taken between Molopolole and Ghanzi there is an increase in the amount of the metamorphic species kyanite, staurolite, andalusite, and epidote westwards, the two first-named being the most abundant. Sillimanite and garnet are very uncommon, even between Ghanzi and the Okavango delta. It is noticeable that the grains of metamorphic minerals are more angular in the west than in the middle and eastern region, while in the east the heavy minerals are more rounded than the quartz grains. Tourmaline and zircon occur in rounded grains and as well formed crystals in almost all the sands, presumably through derivation from sedimentary rocks and directly from the parent rocks respectively. Minerals which may be expected from dolerite and basalt, such as labradorite and augite, seem to be very rare, though ilmenite is always found in quantity and magnetite is present though not abundantly, while the micas are very rare. Well-rounded grains of quartz or other minerals never make up a large part of the sand ; nothing approaching "millet-seed sand" was met with, and the well-rounded quartz grains, like the similarly shaped tourmaline and zircon, give one the impression that they come from sedimentary rocks (17a). In the few samples examined from the country south of the Molopo the variety of minerals seems to be greater than to the north, and garnet is always found in them.

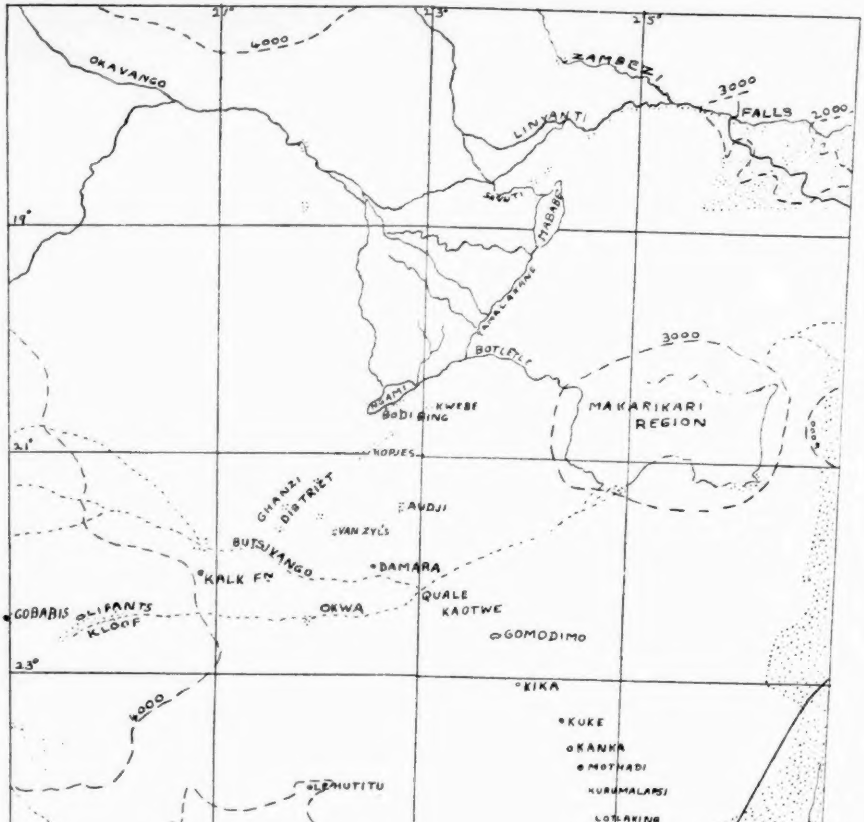
Silica of organic origin is found in most of the sands examined, both in the form of small diatom shells (like *Nitschia* and *Hantzschia*) and as the remains of skeletons of grass (18); sponge spicules are less often seen in the sand. The only samples apparently free from these forms of silica were those taken from a depth of many feet in the Kuke bore-hole. Sand from two to three feet at several spots between Molopolole and Ghanzi contain the organic silica in a fretted condition, possibly due to mechanical damage, but more probably to solution by ground-water, for the fretted state of the diatoms and grass skeletons is obvious also in the limestones. In some of the surface sands the diatoms contained living substance, and it is clear that some of them thrive in the sand when it is wet and that their shells are not carried there by wind (18a). There must be some brought into the

sand-veld by wind, but the rarity of recognisable fragments of the large kinds, such as *Surirella* and *Campylodiscus*, of which the skeletons are abundant in the dry vley deposits of Ngami and Mababe, as well as of smaller kinds like *Melosira*, which are also abundant in the vley ground, indicates that another environment than sand need not be assumed for the small diatoms always found in sand from near the surface (19).

Though both diatoms and the silica from grass can always be seen in sand from the surface, they must form a very small part of it by weight, and I do not think they can provide all the silica deposited as a cementing or replacing material in the sands and limestones of the Kalahari (19a). Of the two kinds of siliceous skeleton those from grass are the more abundant, and they are much stouter objects than the diatoms. In my experience neither carbonates nor silica are at all conspicuous as cementing substances in the Kalahari region away from present or former water channels and pans, except in regions where the bed rock lies near the surface or where the bed rock is calcareous. There are, of course, few opportunities for observation in the sand-veld, because there are few wells and bore-holes far from depressions, but were calcretes and silcretes abundant under the surface there should be many more fragments thrown up near the burrows of animals than we find. Occasionally there are small lumps of sand-grains stuck together by a cement which is partly carbonate of lime, but they are only a fraction of an inch across and do not seem to grow into large masses.

On flat ground between sand-bults in the country from Molopolole to Ghanzi there are often sêen small dark patches consisting of dried algae or other lowly organised plants with filaments lying between sand grains; in wet weather these patches become green and soft. Where these plants are numerous rain water stands longer than elsewhere, and it is possible that they start the formation of sand-pans, which seem to be scattered at random through a very large part of the sand-veld (20); the plants not only make the ground under them less pervious than the loose sand, but they check the wind less than grass, and allow sand blown along the ground to pass over them. Without some means of making small areas in the sand less pervious than the surrounding ground it is difficult to understand how the sand-pans are formed.

The Kalahari marls.—At places between the Molopo and the Koranna-berg apparently unfossiliferous marls occur below limestone or silcrete; they are not often exposed to view, but 20 feet of them were reckoned to lie below some quartzites on the Molopo and 10 feet were seen on the Kuruman River near Gasesa, while Dr. du Toit records 166 feet in a bore-hole near the north end of Korannaberg (21). Mr. Frommurze kindly sent me samples of the marls from the farms Jessievale, Baviaans Kloof, Anglesey, Sandilands, Wyd Beroemd, Ryecroft, Pearson's Hunt, and Magato Spruit.


21°
23°
25°
4000
OKAVANGO
ZAMBEZI
3000
FALLS
2000
LINYANTI
SAVUTI
MABABE
19°
BOTLETLE
NGAMI
KWEBE
BODIBING
3000
MAKARIKARI
REGION
21°
KOPJES
GHANZI
DISTRICT
AUDJI
VAN ZYL'S
BUTSIVANGO
DAMARA
KALK Fn
GOBABIS
OLIFANTS
KLOOF
OKWA
QUALE
KAOTWE
GOMODIMO
23°
KIKA
4000
KUKE
KANKA
MOTHADI
KURUMALAPSI
LOTLAKING
LEHUTITU
3000
MOLOPOLOLE
GABERONES
25
HANYE
NOSSOB
MOROQUEN
4000
MOLOPO
KURUMAN
27°
VAAL
3000
4000
MILES
0
50
100
FALLS
ORANGE
3000

These red or pink marls fall apart in water, and the sand in them includes, in addition to quartz, ilmenite, zircon, and tourmaline in all the samples examined, while epidote, kyanite, garnet, rutile, and staurolite were found in six out of the eight and probably were missed in the other two owing to the amount of marl washed being small; felspar, augite, hornblende, and andalusite were found only in three samples, perhaps for the same reason. Carbonates occur in all the samples except that from Jessievale, and, as in the Kalahari sands, they are in two forms, rice-grains as Dr. du Toit called them, and rhombs. The marl from the Sandilands bore-hole seemed to contain more carbonates than the others, so it was tested quantitatively for them and found to contain 12 per cent., of which 10 were carbonate of lime and 2 carbonate of magnesia. In the other specimens, except that from Jessievale, both lime and magnesia carbonates were found qualitatively. Small black grains or aggregates containing much manganese, and others of iron oxides occur in all the samples. Small crystals of barytes were found in all the marls except that from Wyd Beroemd; the Anglesey sample contained most, so a rough estimate was made from it. The sand which passed a 1-mm. sieve was 10½ per cent. of the sample, and 1 per cent. of the sand grains were crystals of barytes; as the average size of the sand grains is much larger than the barytes crystals, the largest of which is about 0·1 mm. across a diagonal, the barytes probably forms much less than 0·1 per cent. of the rock (22). The barytes, manganese, limonite, calcite, and the dolomitic rhombs appear to be authigenic in these deposits.

Mr. Frommurze also gave me samples from a hole drilled by a rotary machine just over the northern boundary of the Linopen Native Reserve (about 7 miles north of the Mashowing River); there was doubt whether the hole went through Karroo beds, in spite of the red colour of most of the rock, an unusual colour in the Dwyka series. The cores are not laminated and the grains of minerals and rocks up to a quarter of an inch across are not well rounded; the sand grains are of the kinds found in the Kalahari marls, but no barytes was seen; little carbonate was found in these rocks, except in one from 140 feet and another from 416 feet, and the carbonate in the marly samples is in the form of rhombs. The core from 140 feet is a coarse grit with crystalline cement of calcite containing little magnesia;

NOTES ON SKETCH MAP

The outcrops of Pre-Kalahari rocks are indicated by stipples.

The Kalahari deposits are left blank. The approximate positions of known occurrences of Kalahari Marls, mostly in bore-holes, are marked by crosses.

The positions of a few pans, but not their dimensions, are indicated by circles or ovals.

The contour lines and positions are taken from compilations by Mr. E. H. Banks of the Geological Survey of the Union.

there are many brown clayey pellets up to half an inch in diameter containing grains of the minerals found in the sands and marls and in the rest of the calcitic grit. The sample from 155 feet is a hard, red clayey calcareous and magnesian claystone with streaks and patches of white clay and thin veins of white carbonate. These clayey rocks from the Linopen bore-hole do not fall to pieces in water like the marls from the several bore-holes mentioned above. At 170 feet the red mudstone is devoid of carbonates, but at 416 feet a variegated gritty mudstone, rather like that from 155 feet but without veins of carbonate and with coarser grit, contains 28 per cent. of carbonates (15 per cent. of carbonate of lime, and 13 per cent. of magnesium carbonate). The similarity of the mineral grains to those in the marls, and the presence of rhombs of carbonate, which are particularly abundant in the rock from 416 feet, point to the Linopen rocks belonging to the Kalahari group and not to the Karroo beds. The Karroo beds in that region might be expected to contain all the detrital minerals found in the Kalahari beds, except those derived from the dolerites and basalts associated with the Karroo beds, and these minerals were not detected in the Linopen rocks. The small rhombs of carbonates have not been found in the Dwyka sediments examined from the Vaal River, Prieska, and Calvinia; in these rocks the carbonates are in larger patches, not in the form of isolated and easily released rhombs and elliptical grains.

Dr. du Toit recorded 463 feet of Kalahari beds at Dithlaradintsi, with coarse pebbly beds resting on Karroo shales (23). The marly type of deposit is not present at some places in the Kuruman and Molopo valleys where there is opportunity of seeing it, nor has it been proved in the sand-veld north of the Molopo, but in the latter region negative evidence is of very little value as yet. Their extent, however, must be considerable, over 200 miles from the Korannaberg north-westwards, but it is certainly not continuous, and the conditions which brought about their deposition are not known.

The deposits we have considered so far are mainly composed of material brought into the region by wind and water or derived from rocks within it by physical disintegration. The carbonates in the deposits probably came chiefly from the underlying rocks in solution by ground-water and to a smaller extent from outside the present sand-veld in river water. The rocks remaining to be considered, the ferricretes, calcretes, silcretes, and diatom-earths owe their existence to separation of iron oxide, carbonates, and various forms of silica from solution either by simple evaporation and chemical action on existing deposits or, in the case of diatom-earths and part of the carbonates, by plants. Open water in the sand-veld becomes brak as it evaporates, though salt deposits sufficiently substantial to be

worked are rare, and gypsum is seldom seen. I will not attempt to discuss the chemistry of ground-water, though that is obviously the fundamental part of the problem; the feature which distinguishes the Kalahari from a great part of the Union is the absence or the insignificance of run-off, so that substances in solution in the ground-water have much time for chemical activity.

The interrelation of the calcretes and silcretes is certainly very close, for there are many limestones in which a little silica has been deposited, and also many silcretes which contain carbonates. The relation of ferricretes to silcretes is also close, but there seems to be less connection between the ferricretes and the calcretes. It is convenient, however, to describe the three groups separately, because there is usually no difficulty in recognising the chief constituent.

Ferricretes are not well developed in the Kalahari; they are much more conspicuous in the Transvaal and the south-west of the Cape Province. In the country south of the Molopo some ironstone has formed in the white sand at Witsands (24), where the usual red colour of the sand in the southern Kalahari is lacking, but the great sheets of ironstone found on the ferruginous Griquatown beds on the outskirts of the sand-veld have not been recorded from the sand-veld itself (25); the silcretes in the sand-veld have at places enough oxide of iron to be deeply coloured, and they may pass into rocks of which the cementing material is chiefly oxide of iron. On the route from Molopolole to Ghanzi ferricrete was noticed only at Kurumalapsi and near van Zyl's Cütting, but the quantities were small. Passarge recorded it in the Zambezi valley, south of Ngami, near Olifant's Kloof and south of the Makarikari basin (26), and it has been found in many places on the eastern eroded edge of the sand-veld in Rhodesia, where it occurs at the base of the Kalahari beds (27).

Calcretes.—The limestones fall into two groups which are not sharply separated; those which contain fossil water-snails, and those without them. The first group is much the smaller, and to it belong the limestones found in valleys, some pans, and near springs. The second group has a much wider distribution and is familiar to travellers over the Kaap Plateau and many parts of the Upper Karroo; it owes its existence to the deposition of carbonates from rising ground-water on evaporation at the surface or near it. The first group had in part, no doubt, a similar origin, but the molluscs added their shells, and it is not known how much carbonate was deposited from the standing or flowing water in which plants and the molluscs lived (28). In both groups there are varying amounts of sand and clay as well as siliceous skeletons of diatoms and grass, but a limestone obviously belonging to the first group always has very many more diatoms, and a greater variety of them, than are found in the second, though there seems

to be no general difference between them in the quantity of grass skeletons present. The distinction between the two groups is obvious in many instances, but it diminishes owing to the alteration of the limestone by recrystallisation of the carbonates, by their replacement by silica without the production of pseudomorphs of the molluscan shells, and by the destruction of diatom and grass skeletons. The fretted state of the silica skeletons is conspicuous in the limestones. These skeletons can rarely be seen in thin sections of rocks containing them; they are hidden by the minute subdivision of the carbonates and by the non-calcareous matter in the rocks; one has to dissolve away the carbonates to make sure whether the skeletons are in the rocks. The ground-water must be responsible for the corrosion; whether the bicarbonate of lime or some other substances in solution have the greater effect I do not know (28a).

Limestones are conspicuous in places where water lies at intervals or where the bed-rock is not far below the surface, though there are not enough bore-holes far from such places to let one be sure that poverty in limestone there is real and not merely apparent. The great increase in the quantity of limestone in those parts of the country south of the Molopo where the Campbell Rand Series is the bed-rock, and in the Ghanzi district where the Ghanzi beds contain carbonates, while they are much less conspicuous where granite, gneiss, or the Kheis beds occur, indicates that the character of the local bed-rock, or, as in the valleys draining the Kaap Plateau, percolating water carrying carbonates in solution, are important conditions for their formation. In many samples of sand taken far from outcrops of limestone minute crystalline particles of carbonates can be found; some of these particles are elliptical in shape and may reach a length of 0·06 mm., though that is larger than the average; the principal crystal axis is perpendicular to the length. Other particles of carbonate less often seen in the sand are small rhombs; they are less soluble in dilute acid, and they are specially abundant in the calcareous sands such as that from the Kuke bore-hole, which contain a good deal of magnesium carbonate. The bore-hole was made by jumper drill at the eastern end of a pan about a mile and a half long; at about 122 feet a lump or layer of limestone was broken through, but generally the material came up as sand. No diatoms or grass skeletons were found in the sand from low down in the hole, a sample of which gave 52 per cent. of insoluble residue and iron oxide, 35 per cent. of carbonate of lime, and 13 per cent. carbonate of magnesia. Near the western end of the pan there is a shallow water-hole in the white, muddy sand forming the floor of the pan; this white mud contains diatoms, sponge spicules, grass skeletons, and bits of insects and entomostraca; the residue and iron oxide came to 66 per cent., carbonate of lime 31 per cent., and of magnesia 3 per cent. The sands from the two samples contain almost the

same minerals; kyanite, staurolite, and andalusite are in each, but hornblende and sillimanite were only found in the bore-hole sample. The heavy minerals are better rounded than the quartz, as they are in the sands generally. The limestone from 122 feet in the bore-hole has the grains of sand well separated by matrix, chiefly carbonates, but chalcedonic silica forms irregular patches and strings in which minute particles of carbonate are scattered; where the silica is in contact with a quartz grain it is not optically continuous with the quartz of the grain.

Shells of molluscs are scattered sparsely through the limestones containing them; no shell-limestones, in which shells make up the greater part of the deposit, have been recorded from the Kalahari region; the rock with most shells in it yet found there seems to be the calcareous diatom-earth of Witkop near the Hygap (29). Most of the pan limestones seen north of the Molopo are devoid of shells, as they are in Gordonia. Fossiliferous limestone occurs in Matapa Pan (14 miles N.E. of Kuke Pan) (30), Mochumi, Tsho-in, and another pan near Gemsbok Pan; probably many other pans have it, but some which were carefully searched, Kuke, Gomodino, Mothadi, Kaotwe, and others visited between Molopolole and Ghanzi had no shells of mollusca. The limestones of the Okwa River, Mojini Laagte, and the rivers in the Okavango delta, all have shells in them (31).

At a water-hole or well at Mochumi Pan the bed-rock is a green-stained argillaceous quartzite veined by quartz, probably belonging to the Ghanzi beds, and six feet of limestone, pebbly below, lie on it. The pebbles are of quartz, silcrete, and calcrete, and the upper two feet of the limestone are hard and contain shells (Planorbis and Succinea), which also occur in the calcrete pebbles below. The soft limestone from $2\frac{1}{2}$ to 4 feet from the surface has chipped flakes of silcrete in it and fragments of bone, one of which seems to have been shaped by man; pieces of ostrich egg shell also occur in this rock. An apparently artificial flake of silcrete was found in hard limestone at Tsho-in Pan about 4 miles N.W. of Mochumi, and part of this limestone is silicified. It is curious that so few stone implements were seen on the journey in 1930; a rather heavy hand-axe was picked up at a pan $2\frac{1}{2}$ miles N.E. of Gemsbok Pan, and innumerable silcrete flakes on the Kopjes, but none near the pans between Molopolole and the Ghanzi district, though south of the Molopo they occur at pans and water-holes in the sand-veld.

The limestones from 35 places between Molopolole and the Linyanti were tested for magnesia, and in none was it entirely wanting; the rock from the Kuke bore-hole, already mentioned, contains more magnesia than others; a soft limestone from Mochumi Pan had 70 per cent. of calcium carbonate and $1\frac{1}{2}$ per cent. of magnesium carbonate, while the hard lumps enclosed by the soft rock had 77 per cent. of calcium and 2 per cent. of

magnesium carbonate; these hard lumps are fragments of slightly older rock embedded in newer (32).

The outcrops of limestone often have a hard, rather dark crust about half an inch or less thick; this crust looks like a dense limestone, but it can hardly be scratched with a knife, and the outermost part of it, perhaps 1 mm. thick, is weathered white or grey and has a chalky look. A specimen from Kaotwe Pan had 58·3 per cent. of carbonates, while the soft, white rock below the crust had 65·9 per cent. The insoluble residue includes much isotropic, very pale brown material with a refractive index of 1·47, which is higher than that of opal and too low for the ordinary clay minerals; the presence of alumina was proved, but the material experimented on was almost certainly a mixture (33).

Some of the limestones contain barytes. A dense, white limestone which crops out 1½ miles south of Motlhatlogo on the sandy rise from Ngami, a part of Passarge's Kalahari limestone, was found to contain small crystals which proved to be barytes (34), and other limestones, from a pan 1½ miles east of Gemsbok Pan and from Rietbok Pan, contain the same mineral; probably it is in many of the limestones, but unless it is present in some quantity it may easily be overlooked. Gypsum was not found in any of the limestones or pan deposits. The limestone south of Motlhatlogo contains small aggregates of the green mineral which colours so many rocks in the region, both those belonging to the Kalahari System and those (granite, schists, or quartzite) forming the floors of some pans, apparently those which become distinctly brak, such as Kuie Pan in the southern Kalahari, Mochumi Pan in Ghanzi, and Zoutpan in the Waterberg or Limpopo Flats, an eastern outlier of the Kalahari. This green mineral has not been identified and is difficult to isolate in a pure state. The Motlhatlogo limestone offered a better chance of isolating the mineral than other rocks containing it; it is a mica-like, nearly uniaxial, negative mineral containing silica, iron, magnesia, and possibly alumina; its refractive indices are near 1·61. Under the microscope small aggregates of chalcedonic silica are conspicuous in this limestone, but macroscopic bodies of silcrete were not seen in it (35).

Silcretes.—These curious rocks are due to the cementation of whatever lay at or near the surface, to the replacement of carbonates of lime and magnesia, or to the passive deposition of silica in the form of opal, chalcedony, or quartz. They play an important part amongst the visible hard rocks of the Kalahari region chiefly because the bed-rock is usually covered by sand and so cannot be seen, but it is probable that they are comparatively less extensive between the Zambezi and Orange Rivers than in the coast belt from the Cunene round to Kentani and in the country between the Great Karroo and the coast (36). They are very rarely seen in Great

Karroo itself, the Upper Karroo, Orange Free State, Transvaal (37), and Natal; they have not been recorded from the Orange River valley, nor from the lower 150 miles of the Molopo (Hygap). Andrew Bain first found outcrops of them near Tyger Berg ninety years ago, and described them in his paper read six years later (38); he recognised that they belonged to what he called the superficial deposits. Many records of their occurrence are in the Annual Reports of the Geological Commission, but the first detailed petrological investigation was carried out on them by Professor E. Kalkowsky, who used the collection made by Dr. Passarge (39): a more recent and very comprehensive study of this type of deposit, chiefly from the Namib, has been made by Dr. Max Storz (40).

Kalkowsky grouped the rocks into those in which the grains had been cemented by the deposition of silica (eingekieselte) and those which had been derived from limestones by replacement of carbonates by silica (verkieselte). Both classes have been called surface-quartzites by the Cape Survey, which is not an accurate descriptive name because the binding material is often not quartz but chalcedony or opal; G. W. Lamplugh proposed the term "silcrete," which is convenient and less open to objection, so it is often used in English. Storz calls the rocks exogenous "Silicificate," and concludes that they have been produced not only by the "Einkieslung" and "Verkieselung" of Kalkowsky but also by "Durchkieselung," a permeation of very fine grained rocks such as clays, distinguished from the "eingekieselte" rocks only by the minuteness of the infilled pores; and he adds another group formed by deposition of silica jelly as an independent deposit on the surface or in cavities and fissures. This classification is useful, for it accords with what is known about the rocks and is applicable to some of them, but there are very many rocks in the production of which two or more of the processes have taken part, and it may be very difficult to decide that one only has been effective.

The active agent in the production of silcretes is silica, presumably in colloidal solution in ground-water. Ground-water has many substances in solution, and in dry regions the solutions become more concentrated than in wet. In the production of clay from felspar, which is probably the most important source of silica and alkalies in ground-water, silica is set free, and in a wet climate most of it is carried far away from its place of origin, but where there is no run off and too little water to drain away underground, silica accumulates, and on evaporation of the water it is deposited as a jelly which changes into opal, agate, and perhaps quartz, though the proof that quartz in these rocks is derived from opal and not by direct deposition does not seem to have been found.

The study of the silcretes in the Namib, where they are more richly developed than elsewhere, by Dr. Beetz and Professor Kaiser (41), and their

investigation in the laboratory by Storz have increased our knowledge of them very greatly, but it would be a mistake to think that conditions just like those in the Namib are necessary for their production, or that we must assume a similarly low rainfall throughout the coastal region and in the Kalahari because silcretes are abundant there. It is difficult to prove that silcretes are forming to-day in the Kalahari, though that is very likely. At Little Brak River (Mossel Bay), in a region of fairly high rainfall, the formation of chalcedony on salt mud has been recorded (42), and from his examination of the fossil plants in the silcrete of Fort Grey, near East London, Professer Adamson did not draw the conclusion that they lived in a dry climate (43).

The greatest exposures of silcrete in the Kalahari are found on the banks of some rivers, such as the Molopo, Kgolole, Mashowing, one about 30 miles north-west of Molopolole, Tamalakane, Botletle, and Linyanti. Passarge found them well exposed in the Botletle valley, and they form an important part of his Botletle beds. They occur below water level on the Linyanti, Botletle, and Tamalakane, but whether they can form under water is not known; it seems likely that they are not formed there, and that their presence in such positions is due to change in level or to change in the course of the river. They are more widely distributed in or near pans, either in the form of obvious replacements of limestone or as flat crusts formed on or near the surface of the calcareous sandy mud of the pan. Replacement is more conspicuous in the limestones of the pans in the Ghanzi district and in some farther south, such as Heuning Vley and Morokwen, though the long Kuie Pan, where limestone is conspicuous, replacement by silica was not found either in the outcrops or in thin slices. Whether the thin, crust-like silcrete so abundant in the pans of the sand-veld north of the Molopo, such as Mothadi, Kuke, Kika, Gomodimo, and other pans between Molopolole and Ghanzi, and also in the Makarikari region, are formed as such or are replacements is difficult to decide, but replacement has taken place in the limestones and calcareous mudstones in some of these pans (44). In the Okwa valley where Mr. Vernay crossed it there is abundance of limestone, but no silcrete was seen; at Okwa, where Dr. Passarge crossed it about 100 miles farther up the valley, silcrete is well developed (45). At other places in the middle of the sand-veld, such as Kaotwe and the Quale Laagte, there is much limestone but apparently no silcrete. It is difficult to understand why silicification has taken place on a large scale in some of the limestone and apparently not at all in others which seem to be very similar in constitution and circumstances; it may be that the difference is apparent only, and that better exposures would reveal silcretes, but there is a comparable difference in the pan rocks noted above. At the Kalkfontein Pan there are good sections at water-holes showing rather soft lime-

stone in which masses of silcrete first occur about five feet from the surface; some of these masses are $2\frac{1}{2}$ feet long and 8 inches thick; they have been formed by the replacement of carbonates, and they are isolated, many inches or feet of limestone separating them.

On the Linyanti large outcrops of silcrete pass below the water in the river about 13 miles upstream from Kabulabula, and the same kind of rock is found lying on basalt more than 100 feet above the river on the right bank at several places from Kavimba to beyond Kabulabula; if one could be assured that these quartzites were originally continuous at the higher level the lower outcrops would be evidence of a fault; this, however, cannot be assumed, for silcrete can certainly be formed in several positions in one and the same area; the submergence of the lower outcrops may be due to change in the water-level, or to erosion exposing silcrete previously covered by limestone.

Diatom-earths with little carbonates and sand occur in some quantity in Ngami, which is a level stretch about 45 miles long if we include the Doutsa Flats, and at most 7 or 8 miles wide, generally 4 to 5; in 1930 it was covered with vegetation growing in a light soil which is a black, treacherous mud at a few spots marked by clumps of tall reeds. There was no well going down to bed-rock. At Bolibing on the south side of the western end of Ngami, a water-hole 40 feet deep shows a clean section through chalky looking sand with an occasional nodule of limestone half-way down. At the top of the section there is a brown layer about two feet thick containing bits of blackened vegetation. A similar layer is exposed in water-holes at Motlhatlogo farther east; the difference between the brown layers and what lies below is due to the blackened plant fragments and a brown colour given by rusty oxide of iron to the other particles in the deposit, which is made chiefly of sand, clay, diatoms, spicules of sponges, and grass skeletons. At Bolibing the sand 4 feet below the brown layer is whitish and calcareous; it has few sponge spicules, grass skeletons, or diatoms, the latter being fragments of the large kinds of *Surirella* and *Campylodiscus*. The limestone from about 20 feet down the well is sandy and has very few spicules and grass skeletons. The Motlhatlogo water-holes, another at Tololamoro, and one at Toten expose diatom-earths but they contain much sand and clay. Entomostracan shells are often seen in these earths. Carbonate of lime is found only in small quantity in the earths, but thin concretionary layers, up to 2 inches thick, containing the kinds of diatoms found in the earths, are seen in the sides of the water-holes a foot or so from the surface.

Wells in Mababe expose diatom-earth with more lime in it than the Ngami rock, and similar calcareous diatom-earth was brought to me by Mr. Lang from under the sand in the bank of Nata River.

The diatom flora of many rocks collected by Passarge was investigated by Hugo Reichelt (46); the samples from the Botletle and Ngami had the most species, the former 46 and the latter 36. Most of the rocks examined were limestones or calcareous sandstones; he determined 80 species in all, of which 6 only were new, while the rest were living forms, so he concluded that the deposits were of recent date.

The Kalahari System of the interior of South Africa embraces a wide range of rocks which offer a good field for investigation, not only with the purpose of finding out the past history of the Kalahari itself, but also of furthering the interpretation of continental rocks of long past ages.

REFERENCES.

(1) S. Passarge, "Die Kalahari," 1904, chapters xxxiv, xxxvi, xxxvii.

(2) H. B. Maufe, Report of the Director of the Geological Survey of Southern Rhodesia for 1915, p. 4, and "Recent Advances in Rhodesian Geology," Proc. Geol. Soc. S.A., 1919, p. xxii.

(3) S. H. Haughton, "On some Dinosaur Remains from Bushmanland," Trans. Roy. Soc. S.A., v, 1915, p. 259.

A. W. Rogers, "The Occurrence of Dinosaurs in Bushmanland," *ibid.*, p. 265. A. L. du Toit, "The Geology of South Africa, 1926, p. 341.

(4) G. W. Lamplugh, "The Geology of the Zambezi Basin," Q.J.G.S., lxiii, 1907, p. 182.

B. Lightfoot, "Geology of the Central Part of the Wankie Coalfield," Geol. Surv. Southern Rhodesia, Bulletin 15, 1929, p. 43.

(5) In addition to the basalt struck in the Thatchwe bore-hole it has been found in the Khari hole, from which Dr. du Toit sent me samples. The volcanic rocks are not known to have extended over the eastern, southern, and western Transvaal, though the occurrence of agates in the Ermelo district and in some of the diamond gravels of the western Transvaal may point to the former presence of the Karroo basalts in those areas.

(6) Though the southern ranges lie far from the Kalahari their region affords evidence that in early Cretaceous times the great synclinal valleys were filled with material derived from the mountains which came into existence at some date between the deposition of the Ecca beds and that of the Stormberg beds. The date of the mountains may be more closely fixed in future if the necessity should arise of deep boring in the Springbokvlakte area in Steytlerville. (Sheet 150 and Cape Sheet 9, and Explanations by S. H. Haughton.) The outlier of Stormberg sediments and volcanic rocks south of Zuurberg, taken together with their uncleaved condition in contrast to the disturbed state of the Dwyka series in the same area, points to an unconformity at some horizon in or below the Cave Sandstone there and supports the earlier surmise that the boulders in the Molteno beds came from the southern ranges.

(6a) A. L. du Toit, "Report on the Kalahari Reconnaissance of 1925," 1926; and "The Kalahari and some of its Problems," S.A. Journ. Science, 1927, pp. 88–101.

(7) The fossil shells recorded by Passarge from the northern region ("Die Kalahari," 1904, pp. 754–59) are:

Succinia arborea, Mousson.
,, *Moussoni*, v. Martens.
Buliminus (*Leucocochloides*) *minusculus*, Mousson.
,, *Damarensis* ? var. *expectatus*, Mousson.
Planorbis salinarum, Morlet.
Physa parietalis, Mousson.
Ampullaria occidentalis, Mousson.
Lanistes ovum, Peters.
Vivipara Passargei, v. Martens.
Cochlicella opposita, Mousson.
Melania tuberculata, Muller.
Unio Kunenensis, Mousson.
Corbicula africana, Krauss.

None of these species was mentioned by Boettger in his list of the shells from Witkop in Gordonia in L. Schultze's "Aus Namaland und Kalahari," Jena, 1907, pp. 706–8; see also Ann. Rep. Geol. Comm. for 1907, pp. 107–8.

The collection of land and fresh-water snails made by members of the Vernay-Lang Kalahari Expedition in 1930 has not yet been reported upon: Major Connolly kindly identified some shells from limestones which I took to him, including *Lanistes*, *Viviparus Passargei*, and *Melania tuberculata* from the Linyanti and Ngami limestones, and *Burnupia trapezoides* (an *Ancylus* of Boettger's list) from Matapa Pan besides probable identifications of *Bulinus tropicus* and *Planorbis gibbonsi* Nelson, from the Okwa, Ghanzi, and Matapa limestones. The fossils are often difficult to get out and a more thorough examination must await the report on the recent shells. It should be noted that in my collection no bivalves occur, and that the conspicuous northern genera *Lanistes*, *Ampullaria*, *Melania*, and *Viviparus* are not found in the rocks from Ghanzi, Quale, Okwa, Matapa, and other places south of Ngami and the Okavango region.

(8) In his paper "Crustal Movements as a Factor in the Geographical Evolution of South Africa," S.A. Geog. Journ., xvi, December 1933, Dr. du Toit suggests that the Basuto Highlands used to stand much higher relatively to the surrounding country than they now do, chiefly to satisfy isostasy. There is difficulty in accepting this view because on it one would expect a much greater development of river gravels due to the reduction of river grade involved in the rising of the surrounding country. It also introduces difficulty in explaining the Kaap-Stormberg peneplain, which Dr. du Toit first recognised ("The Evolution of the River System of Griqualand West," Trans. Roy. Soc. S.A., i, pp. 349–55) and which he thought was produced when the continent stood at a much lower level than it now does, even suggesting greater uplift of the Drakensberg region than of the rest of the country, a view that seems to be in better agreement with what we know of the rivers and the relative rates of denudation of a mountain region and the surrounding lower country.

(9) G. W. Lamplugh, "Note on the Geological History of the Victoria Falls," Geol. Mag., December 1905, and Q.J.G.S., lxiii, pp. 167–8.

(10) H. B. Maufe, "Some Problems in Rhodesian Physical Geography," S.A. Journ. Science, xxiv, 1927.

(11) A. L. du Toit, "Crustal Movements as a Factor in the Geographical Evolution of South Africa," S.A. Geog. Journ., xvi, p. 9, 1933, gives the name Griqualand-Transvaal Axis to this structure and attributes to it the increase in grade of the Orange River at Buchuberg and that of the Hartebeest River between Verneuk Pan and Kenhardt; these increased grades, however, coincide in position with outcrops of harder rock than usual—Matsap beds of the Langeberg-Ezel Rand at Buchuberg and the granite floor below the Karroo beds on the Hartebeest River—which must have checked downward erosion, and therefore lowered the grade, in the valleys above them. It was to this circumstance that I attributed the position of Verneuk Pan (Trans. Roy. Soc. S.A., ii, 1911, p. 82), and it seems a more likely explanation than the presence of an anticline, for the form of the outcrop of the almost flat Dwyka series in that part of the country does not seem to be that of a broad or narrow anticline. I think that Dr. du Toit's earlier opinion given in the paper quoted above (Trans. Roy. Soc. S.A., i, p. 349) that there has been no warping of the Karroo beds over the area embraced by the Kaap-Stormberg peneplain in Kenhardt and Prieska is nearer the truth than his later view.

(12) P. Range, "Topography and Geology of the German Kalahari," T.G.S.S.A., xv, 1912, pp. 63–73, and in Beitr. z. geol. Erforsch. d. Deutschen Schutzgebiete, Hft. 11, 1915, for details of bore-holes in the region.

H. F. Frommurze, "Bore-holes in Rehoboth, Gibeon, and Gobabis, S.W.A.," T.G.S.S.A., xxxiv, p. 124.

(13) A. W. Rogers, Ann. Rep. Geol. Comm. for 1907, p. 96. S. H. Haughton, Trans. Roy. Soc. S.A., xiv, 1927, p. 228.

(13a) A. L. du Toit, Ann. Rep. Geol. Comm. for 1905, p. 255.

(14) Ann. Rep. Geol. Comm. for 1906, p. 61, and for 1907, p. 188.

(15) Ann. Rep. Geol. Comm. for 1906, p. 76–78.

(16) A. M. Macgregor in Report by Mr. Jeffares on the Rhodesia-Walvis Bay Reconnaissance Survey, 1932, p. 45.

(17) The results of sieving some sands were as follows for samples:—

1. from 196 miles on road from Gaberones to Ghanzi.
2. ,, 200 miles on same road.
3. ,, Kaotwe, surface.
4. ,, Kaotwe, 3½ feet below the surface.
5. ,, 2 miles N.W. of van Zyl's Cutting.
6. ,, 2½ miles N. of Gemsbok Pan.
7. ,, 12 miles S.W. of Quagganai.
8. ,, River bed at Toten, from a well.
9. ,, Well on northern edge of Ngami at Tololamoro.
10. ,, Bolibing pit, 4 feet down. S.W. end of Ngami.
11. ,, White sand in Mopani bush near Mababe Flat.
12. ,, Red sand near Victoria Falls.
13. ,, White sand from Witsands in southern Kalahari.

For comparison the following sands from other places were sieved:—

14. from Red sand, Intermediate Pumping Station, Kimberley Water Works (A.L.d.T.).
15. ,, Red sand, Klokfontein Siding, Kimberley. (A.L.d.T.).
16. ,, Glencairn beach, Simonstown.
17. ,, Kaffir Kuil River Mouth (Dr. Muir).
18. ,, Nordkappers Kop. (Dr. Muir).

No.	Held on 1 mm. sieve.	Passed 1 mm. held on 40 mesh.	Passed 40 held held on 50 mesh.	Passed 50 held held on 120 mesh.	Passed 120 mesh.
					per cent.
1	0·15	0·6	2·7	54·7	40·4
2	0·2	0·6	4·9	60·4	33·4
3	0·0	0·5	2·0	67·7	31·6
4	0·0	0·1	2·6	65·8	31·3
5	0·6	0·9	1·9	68·8	27·6
6	0·02	0·3	1·1	53·0	45·5
7	0·4	1·1	4·9	66·4	27·2
8	0·3	0·4	1·4	88·0	9·3
9	1·1	1·0	1·7	59·6	36·6
10	0·3	1·2	4·1	59·6	33·8
11	0·13	1·6	3·7	63·5	30·4
12	0·4	8·2	15·5	49·2	26·7
13	0·0	0·1	3·5	61·5	34·1
14	0·2	0·7	3·4	46·6	49·0
15	0·1	2·7	4·9	47·8	44·4
16	6·0	11·0	14·0	65·0	4·0
17	0·07	0·07	0·16	66·3	33·4
18	0·2	2·6	13·2	75·4	8·6

(17a) The sands which have come to be called "millet-seed" are perhaps larger in grain than the Kalahari sands: those known to me are: Penrith and St. Bee's sandstones, Lickey quartzite, Taquara sandstone (a Brazilian rock corresponding to our Cave Sandstone or Red Beds, of which a specimen was given me by Dr. du Toit), and the spherical grains of the "sago" quartzites of the Witwatersrand and Black Reef formations.

M. L. CAYEUX, in "Roches Siliceuses," 1929, p. 75, says in reference to the sphericity of desert sands: "I was much surprised when, turning from the literature and looking at the facts, I found that the exception had generally been made the rule." My experience agrees with that of M. Cayeux.

(18) These variously shaped bodies of opaline silica, chiefly spade-shaped or knobbly rods, are profusely illustrated in G. C. Ehrehberg's "Mikrogeologie," 1854 (a copy is in the library of the South African Museum) under the general name of "Phytolitharien," but without description or explanation; I had difficulty in finding what organisms they came from, but a reference in Früh and Schröter's "Moore der Schweiz," 1908, p. 144, states that they are the siliceous skeletons of grass, and examination of the residue from bits of grass boiled in Schultze's solution confirmed that statement. Reichelt, in "Die Kalahari," p. 761, refers to them, a statement that I had missed. Kalkowsky, writing of the salt mud collected by Passarge ("Die Verkieselung der Gesteine in der nordlichen Kalhari," Abh. d. naturwis. Gesellschschaft. "Isis" in Dresden, 1901, p. 66–67) says: "The reeds die off; they contain silica in their tissues which reach the basin in very fine flocks and particles associated with organic matter. I have not been able to discover from books on botany the fate of the silica in dead plants; it must in any case either remain or be removed in the solid state or in solution. We only know the siliceous remains of diatoms."

(18a) Professor H. B. FANTHAM kindly examined twelve samples of Kalahari sands for protozoa; the results are included in a paper by him on "Soil Protozoa found in certain South African Soils, X," in the South African Journal of Science, 1931,

pp. 336–40. In a letter to me he wrote that occasionally in his work on other sandy soils diatoms overran the cultures made under bacteriologically sterile conditions; this was in answer to an enquiry of mine after I had seen living diatoms in some of my samples, for I did not know they lived in soils.

(19) The quickest way to find the diatoms and the grass skeletons in dry sand is to place the sand on a dry glass slip and let it fall off gently by tilting the slip; some dusty material will remain on the slide, and a drop of clove oil or balsam and a cover-glass on it will let the siliceous bodies be found easily.

(19a) H. Reichelt in "Die Kalahari," p. 783, expresses the opinion that redepositon of silica from diatoms was an important process in the formation of the silicified rocks of the Kalahari; that it took part in the making of these rocks is certain, but the quantity of diatoms is insufficient for the purpose, except in the diatom earths, and these are the one type of deposit in which silicification, on a macroscopic scale at least, has not been noticed.

(20) The distribution of the sand-pans will be well known only when a map of the country has been made from the air. The observations of travellers such as Chapman, Andersson, Woosnam, and Passarge furnish evidence that these pans are both frequent and distributed at random north of the Molopo; they certainly seem to be so between the Molopo and Orange Rivers. Professor Fritz Jaeger ("Kalkpfannen des östliches Südwestafrikas," in the Report of the XVIth International Geological Congress, Washington, 1933, reprint dated 1936, pp. 10–11) thinks that the limestone pans of S.W.A. chiefly lie along the courses of former rivers, and the elongated form of pans like Kuke and Gomodimo, which hardly come under that class of pan, though they contain much carbonate of lime, give the traveller the same impression.

(21) A. L. du Toit, Ann. Rep. Geol. Comm. for 1907, p. 151, and "Geology of South Africa," p. 369. A. W. Rogers, Ann. Rep. Geol. Comm. for 1907, p. 106.

(22) The barytes in these marls was found after that mineral had been determined from the Ngami limestone described on a later page.

(23) "Geology of South Africa," p. 370.

(24) Ann. Rep. Geol. Comm. for 1906, p. 72.

(25) Ann. Rep. Geol. Comm. for 1906, pp. 74–76; for 1907, p. 147.

(26) "Die Kalahari," pp. 120, 516, 358.

(27) H. B. Maufe, Rep. Dir. Geol. Survey of S. Rhodesia for 1915, pp. 4–5, and "The Karroo and Kalahari Rocks of the Gwampa Valley," Proc. Rhod. Sci. Association, xx, 1922, p. 5.

J. C. Fergusson, Short Report, No. 29 (Geol. Surv. S. Rhod.), p. 5.

(28) Heinz Michaelsen, "Die Kalkphannen des östlichen Damaralandes," Mitt. a. d. deutsch. Schutzgebieten, 1910, Hft. No. 3, p. 32 of reprint, points out the importance of plants in causing the deposition of carbonate of lime in the pan waters.

(28a) H. Reichelt in "Die Kalahari," p. 783, after quoting Frenzel and Marsson on the solution of diatom shells by water alone or by water containing bicarbonate of lime, attributes the effect in the Kalahari to water, warmth, and lime, but he adds that the process is not understood. He thought that the poverty in species in some limestones was due to the destruction of thin-shelled kinds; but this does not agree with the presence of thin-shelled species in such limestones as those of the Okwa and Quale, nor with the occurrence of only thin-shelled species in many of of the limestones.

(29) L. Schultze, "Aus Namaland und Kalahari," 1907, pp. 706–8, and Ann. Rep. Geol. Comm. for 1907, p. 107.

(30) I did not visit Matapa Pan: the limestone from it was given me by Mr. Vernay. It contains *Burnupia*, *Planorbis*, and *Bulinus*. Mr. Vernay thought the place looked more like part of a laagte than an isolated pan.

(31) These shells are of different groups: see note (7).

(32) R. B. YOUNG in "The Calcareous Rocks of Griqualand West" (Trans. Geol. Soc. S.A., ix, 1906, p. 58), quotes three analyses of surface limestones from the Kaap Plateau giving 1·57, 2·8, and 18·57 per cent. of magnesium carbonate. S. Passarge quotes three, a pan sandstone from Nakais, and Kalktuffs from Lotlakani and Kalkfontein with no magnesium carbonate: in six others of his specimens 0·8 to 10·0 per cent. were found ("Die Kalahari," p. 753). W. Wybergh's samples of surface limestones from Bechuanaland within the Union had from 1½ to 25 per cent. of magnesium carbonate ("Limestone Resources of the Union," 1918, vol. i, ch. xi).

(33) The refractive index of the aluminous material is about that ascribed to allophane in Larsen and Barman's Tables (Bull. 848 of U.S. Geol. Survey), but allophane is a very soft mineral.

(34) The mineral was separated from the insoluble residue of the Motlhatlogo limestone and found to be a sulphate; I took it to be celestine on account of its shape, but could not get a reaction for strontium; Mr. Partridge kindly examined it in the laboratory of the Geological Survey, Pretoria, and proved the presence of barium together with very little calcium and strontium by the spectroscope.

(35) Mr. Partridge found iron and magnesia by the spectroscope and by microchemical tests, but no alumina: I found alumina after fusion with soda, but the sample was not pure. The refractive indices are about 1·61.

(36) Ann. Rep. Geol. Comm. for 1897, p. 68; for 1898, p. 51; for 1901, p. 66; for 1903, p. 164; for 1904, p. 44; for 1906, pp. 74, 81; for 1907, pp. 96–112, 149–55; for 1911, pp. 78–81.

(37) Explanation of the Heidelberg (Tvl) Sheet, p. 69.

(38) Trans. Geol. Soc., Second Series, vii, p. 192.

(39) E. KALKOWSKY, "Die Verkieselung der Gesteine in der nördlichen Kalahari," Ab. d. naturwis. Gesellschaft. "Isis" in Dresden, 1901.

(40) MAX STORZ, "Die Diamantwuste Südwestafrikas," 1926, vol. ii, ch. xxv, and "Die Sekundare authigene Kieselsaure . . ." Berlin, 1928, 478 pp., 25 plates, and 202 text-figures.

(41) E. KAISER and W. BEETZ, "Die Diamantwuste Sudafrikas," 1926.

(42) Ann. Rep. Geol. Comm. for 1905, p. 296.

(43) Annals of the South African Museum, xxxi, 1934, pp. 67–96. The silcretes of Fort Grey lie on decomposed dolerite and are chalcedonic rocks; an examination of the slices which Professor Adamson had cut shows that little opal is in them now, and no carbonates.

(44) Samples of the silcrete lying on the surface of the eastern part of the Makarikari were brought to me by Mr. Douthwaite. They are of two kinds—one is dull green and has many obvious grains of sand in it, and its surface is rough; the other is white, with a conchoidal fracture like that of fine porcelain but smoother. On examining the crushed rocks the green silcrete is seen to be opal, enclosing great numbers of irregularly shaped, minute particles of carbonate, about 0·002 mm. wide, which can be removed by acid, flakes of the green mica-like mineral referred to on p. 70 and in note (35), fragments of diatoms and of grass skeletons, which can be seen after removal of the carbonate. The opal does not appear to have replaced carbonates but to have been deposited round whatever lay there. The white rock

is made of chalcedony, and no grains of sand or plant skeletons were seen in it: a very few particles of carbonate were seen in it.

(45) "Die Kalahari," p. 345.

(46) "Die Kalahari," pp. 760–84.

Postscript.—Just before this address was completed I received from Mr. Maufe the typescript of an important paper "Some Factors of the Geographical Evolution of Southern Rhodesia and Neighbouring Countries," which will be printed in the forthcoming volume of the South African Geographical Journal, vol. xviii. Mr. Maufe's paper is not concerned with details of the Kalahari deposits but with the origin of the floor on which they rest, the Pre-Kalahari Peneplain, and its probable identity with the Kaap-Stormberg peneplain referred to in notes (8) and (11).

THE RELATION BETWEEN THUNDERSTORMS AND ATMOSPHERICS IN SOUTHERN AFRICA.

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(With Plate VI and two Text-figures.)

(Read October 16, 1935.)

The application of the Cathode Ray Oscillograph to the determination of the direction of arrival of atmospherics at a station has been developed by Watson Watt and his co-workers at the Radio Research Station at Slough.* The device they have evolved employs the well-known principles of radio direction finding to obtain, on the oscillograph screen, an instantaneous and direct reading of the true bearing of the source giving rise to any single atmospheric reaching the station with sufficient energy to operate the instrument.

It is clear that, if two such bearings of the same source are obtained at different stations, a fairly accurate location of the position of the source may be made, whereas a single bearing from one station merely gives the direction of the source. The amplitude of the disturbance recorded on the instrument from a source will depend, however, amongst other things, on the distance between source and station. It is therefore possible, even with a single station, to obtain an approximate estimate of the distance of the source from a consideration of the average amplitude of the records on the instrument.

Considerable evidence has been advanced by Watson Watt to show that the great majority of atmospherics, if not all, originate in regions of disturbed weather, and are associated with electrical disturbances of the nature of lightning. A similar conclusion has been reached by Munro and Huxley † as the result of extensive investigations carried out by them in Australia. The Cathode Ray Direction Finder thus makes it possible to

* "The Cathode Ray Oscillograph in Radio Research," by Watson Watt, Herd, and Bainbridge Bell (H.M. Stationery Office).

† "Atmospherics in Australia," Report No. 5, Radio Research Board, Australia. A further valuable report, No. 8, 1935, has reached us too late for consideration in this paper.

determine the location of disturbed weather conditions within a radius of 2000 miles or more of any station. For this reason the method is likely to be of value in meteorological forecasting, and it has already been successfully employed in this way in Australia.

At the present time the Government Meteorological departments in Southern Africa depend for their information of local weather conditions on reports from observers at various points scattered over the sub-continent. With such a large and thinly populated area to be covered this method has obvious disadvantages, and it is impossible for the departments concerned to obtain complete records. They are further handicapped by an absence of reports on weather conditions over the oceans in their neighbourhood, which would greatly facilitate weather forecasting. The proposed establishment of a meteorological station at Tristan d'Acunha, which would supply information of depressions in the Atlantic Ocean, would have its value greatly enhanced, as far as South Africa is concerned, if means were available for following their direction of movement. The report system has a further disadvantage in the delay which occurs in reports of disturbed weather conditions reaching the meteorological offices. This is of special importance in the case of air-routes, and a rapid and practically instantaneous means of locating thunderstorms and heavy rainstorms along such routes would be of great value.

It thus appeared desirable to explore the possibilities of the use of the Cathode Ray Direction Finder in South Africa, and the present paper contains an account of a preliminary investigation on these lines using a single station located at Cape Town.

Description of Apparatus.

The principle of the apparatus has been fully described elsewhere,*† and only a brief description will be given here.

Two identical frame aerials are set up close together, their planes vertical and at right angles to each other, the one along the North-South, the other along the East-West geographical meridian. If an incoming electro-magnetic wave is such that the horizontal component of its magnetic vector makes an angle A with the plane of the N-S loop, it will induce in this coil an alternating E.M.F. proportional to cos A, and in the other coil an E.M.F. proportional to sin A. If these two E.M.F.'s, after equal amplification in both gain and phase, be applied respectively to the y and x deflecting plates of the oscillograph, the resultant trace on the screen

* Watson Watt, *et alia*, *loc. cit.*, p. 162.

† Watson Watt, *et alia*, *loc. cit.*, p. 162; "Radio Direction Finding with the Cathode Ray Oscillograph," by D. B. Hodges, Journ. S.A. Assoc. for Adv. of Science, 1935.

produced by their combined effect will be a straight line making an angle A with the y axis of the oscillograph, thus giving a direct reading of the direction of the incoming wave.

The frame aerials used by us were 1 metre square, and consisted of 100 turns of wire with a spacing of 0·5 cm. between the turns. Each coil had a resistance of 12 ohms, and its self-inductance was found to be 14·3 mH. Each coil was tuned by a fixed condenser of capacity 0·015 mfd., so that signals were received at a frequency of 10·86 kc./sec., corresponding to a wavelength of 27·61 kilometres. The signals were then directly amplified at this signal frequency by means of two carefully matched amplifiers. Each of these had four stages of resistance-capacity coupled amplification, using L.S.5.B. valves. A gain control on the third stage in each amplifier provided a means of adjusting the amplitude of the final signal on the oscillograph. Actually full gain was never employed in this work.

The oscillograph tube used was a Type A Cossor Cathode Ray Oscillograph. The compass dial was inscribed on the fluorescent screen of the tube by an electrical method.* Three concentric circles were then inscribed on the face with the stationary spot as centre, of radii 0·5 cm., 1 cm., and 2 cm. respectively. These were used to provide a rapid means of estimating the amplitude of any given signal. A general view of the experimental arrangement, showing the frame aerials, amplifiers, and cathode ray oscillograph with compass dial, is shown in Plate VI.

The methods used for the matching of the frames and amplifiers both for gain and phase, were those laid down by Watson Watt † under the head of "lining up." In this process a sealed oscillator was used to inject into one or both of the aerials a known E.M.F. This oscillator was of the usual Hartley type, tuned to the required frequency, and enclosed in a welded iron box with a mercury seal, as perfect screening of the oscillator is essential.

The various stages in this "lining up" process are, briefly, as follows:—

(*a*) A strong signal from the oscillator is injected into one aerial, while the other aerial is connected through its amplifier, set at maximum gain, to the plates of the oscillograph. If any signal is indicated, it shows that coupling exists between the two coils. The second coil is then moved in its own plane until no signal is indicated on the oscillograph.

(*b*) The two sets of oscillograph plates are connected, thus throwing the signal from the test oscillator equally on to both sets. The resultant signal on the oscillograph disc will be a straight line at 45° to the axes, known as the reference line. The amplifiers are then matched, stage by stage, by commoning their respective

* Watson Watt, *et alia*, *loc. cit.*, p. 162. † Watson Watt, *loc. cit.*

inputs. Any departure from equality of gain is shown by a deviation from the reference line, and can be adjusted by the gain controls. (If careful matching of components has been adopted in construction, this is usually found to be inappreciable.) If inequality of phase exists, it is indicated by the signal becoming an ellipse instead of a straight line. This is adjusted by means of a phasing condenser in the one amplifier.

(*c*) With the amplifiers matched, any deviation from the reference straight line in the signal from the oscillator injected equally into both frames must be due to faults in the frames themselves. These are finally adjusted by means of a variable condenser in parallel with the fixed tuning condenser on one of the frames.

Methods of Observation.

After the process of "lining up" is completed, the gain controls are adjusted so that the signal from the test oscillator has a given amplitude (usually 1 cm.). This is done so that use may be made of the amplitudes of the signals from various sources and on various days for comparison purposes. The oscillator is then switched off, and readings taken over a stated period. One observer watches the dial, and, as each signal is observed, calls out its direction and amplitude. These are taken down and tabulated by an assistant. It was found that greater accuracy could be obtained by allowing the observer to concentrate on observing alone, instead of tabulating his own observations. Directions could be estimated with an accuracy of $\pm 3^\circ$, and amplitudes were obtained by means of the concentric circles on the dial. In this preliminary work no arrangements were provided for obtaining the sense of the direction of the signal. With the apparatus as so far described, signals both from the North-West and from the South-East, for example, would give the same straight line on the dial at 45° to the axes. Continuous observations were made for a period of about ten minutes each day the instrument was in operation, usually in the afternoon between 2 p.m. and 5 p.m. local time. In a few cases morning and night observations were made, mainly to test whether any general variation in amplitude was noticeable.

We are greatly indebted to the Chief Meteorologist, Irrigation Department, Pretoria, and to the Chief Meteorologist of Southern Rhodesia, who kindly supplied us with the meteorological maps compiled by their respective offices covering the period of our investigation. It was thus possible to compile maps on which were plotted the bearings given by the direction finder together with the meteorological information from the departmental maps. From this information we were able to ascertain the range of the

instrument, which was found to be about 2000 miles from Cape Town in the afternoon. Sources correlated with actual thunderstorms ranged in distance from 350 miles to 1000 miles from Cape Town.

Table I is an extract from the log book showing a typical set of observations on one afternoon. Observations were made on 26 days between 3rd September 1935 and 18th October 1935.

TABLE I.

Date:	October 9th, 1935.	Oscillator Calibration	1 cm.
Time:	$13\frac{1}{4}$ hours.		
Run:	10 minutes.	Observer	D. B. H.

W.	←—N—→		E.	
30°	1°	15°	45°	70°
10	10		6	8
10	7	Continuous	8	20
8	5	Amp. 5.	10	10
	8			8
	10			10
	8			10
	8			10
	8			10
				8
				10
				10

GENERAL SURVEY OF RESULTS.

The series of maps shown in figs. 1 and 2 cover the period of the investigation, and we have included a map for each day on which readings were made with the instrument, with no omissions. The straight lines indicate the bearings of sources of atmospherics as given by the Cathode Ray Direction Finder. Against each bearing there are three symbols.

1. M. A. or E. indicated that observations were made in the morning, afternoon, or evening.
2. The second symbol indicates the *average* amplitude of the signals on the compass dial from that particular bearing in millimetres reduced to a common level for comparative purposes. This standard setting for amplitude is that which gives a deflection of 1 cm. from the standard oscillator, and represents an input field strength of 1020 micro-volts/metre.
3. The third symbol indicates the average frequency of the signals from

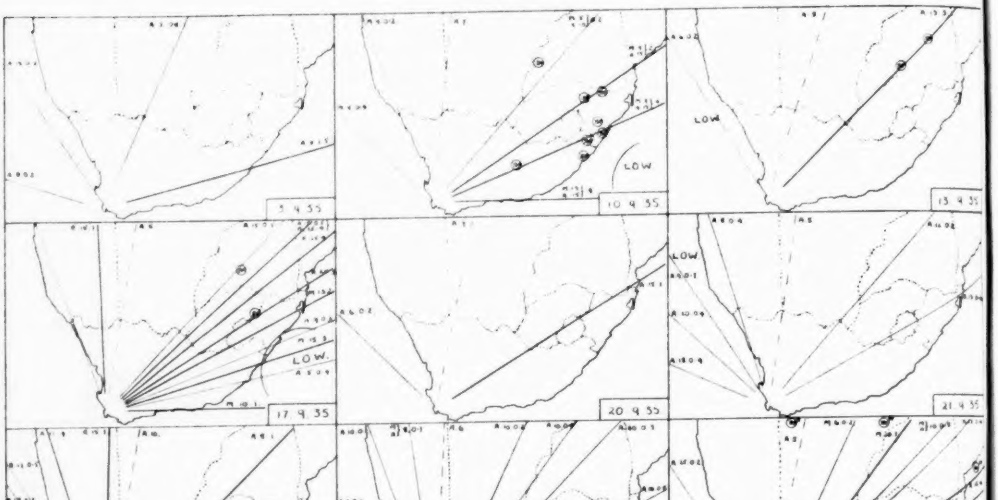

5. 9. 35
10. 9. 35
13. 9. 35
17. 9. 35
20. 9. 35
21. 9. 35
23. 9. 35
24. 9. 35
25. 9. 35
26. 9. 35
27. 9. 35
28. 9. 35
29. 9. 35
1. 10. 35
2. 10. 35
LOW

Fig. 1.

a particular source, the figures giving the average number per minute during the period of observation. Where this average frequency exceeds 1 per minute, a heavier straight line has been used to indicate the bearing.

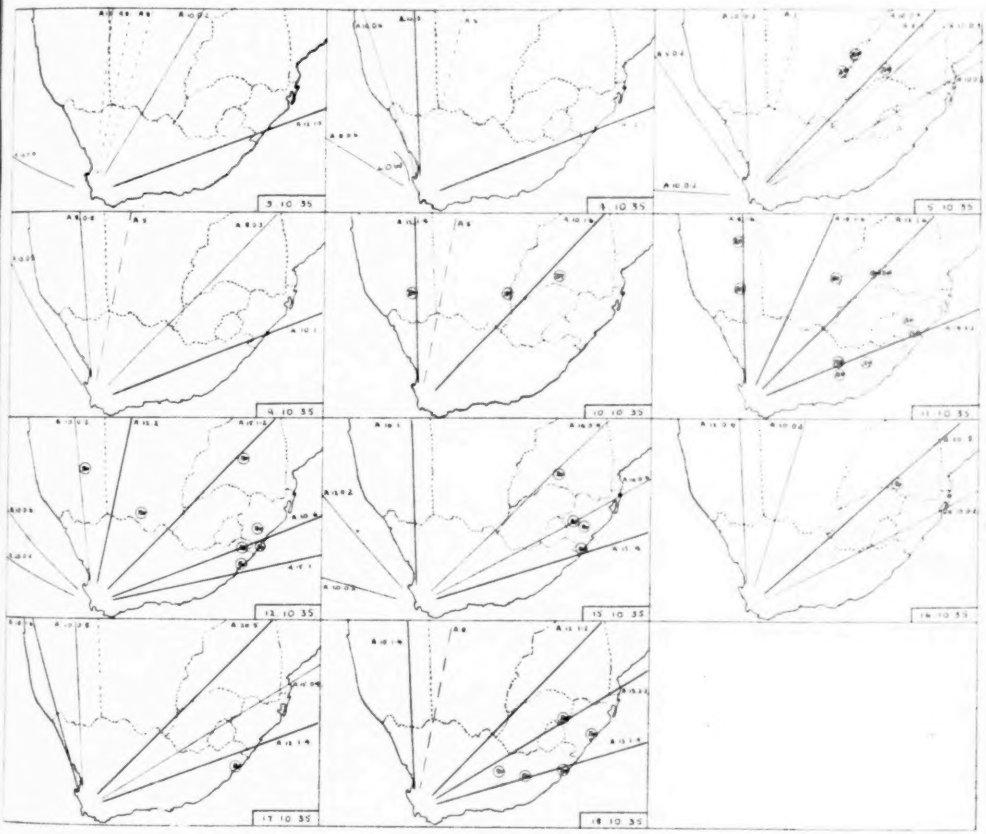


Fig. 2.

In general it was found that afternoon signals came in continuously with an amplitude of about 0·5 cm. from the well-known active area of the Congo watershed. This source, actually extending in bearing from 5° to 15° E. of N., is shown on the maps by a dotted line, and in our observations we usually neglected it for the closer study of nearer sources.

Relation between the Bearings of Atmospherics and Reported Thunderstorms.

During the period under review the meteorological maps indicated that thunderstorms were reported as having occurred in fifty-four different places. In 35 (65 per cent.) of these cases atmospherics were detected, during the running of the instrument, with bearings lying within 3° of that of the reported thunderstorm, and in 48 (89 per cent.) of these cases the bearing lay within 5° of the reported thunderstorm. When it is remembered that the usual time devoted to the making of observations with the direction finder was ten minutes per day, while the meteorological reports cover the whole twenty-four hours, the agreement is striking.

In all a total of 174 bearings on sources of atmospherics was obtained during the experimental period, 57 being from sources located in the Atlantic and Indian Oceans, and 117 from sources over the land. Of these latter land sources, 27 (23 per cent.) gave bearings within 3° of those of thunderstorms actually reported on meteorological maps, and 15 (13 per cent.) were associated with the active region of the Congo watershed previously mentioned. Of the remainder, 37 (31·5 per cent.) were from directions indicating sources in S.W. Africa, the Kalahari, or Bechuanaland, all regions where the meteorological report system is practically non-existent, and 38 (32·5 per cent.) were from other land sources. If those directions which the report system is known not to cover be neglected, then of the 80 recorded bearings 42 (52·5 per cent.) are found to be definitely associated with thunderstorms. When it is remembered that the report system, even in the more populous areas, cannot be expected to report every thunderstorm which occurs, and, further, that a certain number of the uncorrelated signals were of small average amplitude, and thus might very well be associated with depressions in the Indian Ocean, it is reasonable to conclude that the lightning flash is the chief, if not the only, source of the atmospherics received. In the course of this work our observations have given us no indication of any other source of atmospherics.

Ocean Atmospherics and Coast Pressure Records.

In South Africa there are practically no meteorological data available with regard to weather conditions at any appreciable distance from the coast on the Atlantic side of the sub-continent. On the Indian Ocean side a certain amount of information can be deduced as to the existence of "highs" or "lows" at sea from meteorological reports and occasional reports from ships from India and Madagascar. An analysis of the bearings

obtained with the Cathode Ray Direction Finder of sources located at sea is therefore of interest.

Atlantic Ocean Sources.

Sources of atmospherics were located in the Atlantic Ocean on 20 different days. On 4 of these days (13th and 21st September, 4th and 9th October) there were definite "lows" shown on the meteorological maps off the west coast in the region of Port Nolloth. The bearings and amplitudes on these 4 days are shown in Table II. These indicate sources about 1000 miles away from Cape Town.

Table II.

Bearings of Atlantic Sources on Days of West Coast "Lows."

3 at 30° of amplitude (average)	. .	8 mm. *
1 ,, 45° ,, ,,	. .	20 ,,
1 ,, 60° ,, ,,	. .	8 ,,
1 ,, 65° ,, ,,	. .	19 ,,
		Average—12 mm.

On 9 of these days (10th, 20th, 25th, 26th, 29th September; 2nd, 3rd, 12th, 15th October) there was a general decrease in pressure on moving north along the coast from Cape Town, suggesting the presence of a "low" at sea approximately 1000 miles away. The bearings and amplitudes of the signals received on these days are shown in Table III.

Table III.

Bearings of Atlantic Sources on Days of probable near Atlantic "Lows."

2 at 30° of amplitude (average)	. .	16 mm.†
1 ,, 35° ,, ,,	. .	5 ,,
2 ,, 40° ,, ,, ,,	. .	8 ,,
5 ,, 45° ,, ,, ,,	. .	10 ,,
3 ,, 60° ,, ,, ,,	. .	13 ,,
4 ,, 75° ,, ,, ,,	. .	7 ,,
		Average—13 mm.

On the remaining 7 days (3rd, 23rd, 24th, 27th, 28th September, 1st, 5th October) definite "highs" were recorded off the coast at or beyond Port Nolloth.‡ The bearings and amplitudes of the signals received on these days are shown in Table IV.

* 1 mm. = 102 μ volts/metre.

† 1 mm. = 102 μ volts/metre.

‡ We are indebted to Mr. N. Sellick, Meteorologist to the Government of Southern Rhodesia, for the information that on all except one of these days (5th October), known

TABLE IV.

Bearings of Atlantic Sources on Days when no near "Lows" were present.

1 at 20° of amplitude		5 mm.*
4 ,, 30° ,, ,,	(average)	5 ,,
1 ,, 35° ,, ,,		4 ,,
5 ,, 40° ,, ,,	,,	6 ,,
2 ,, 45° ,, ,,	,,	13 ,,
2 ,, 60° ,, ,,	,,	5 ,,
2 ,, 75° ,, ,,	,,	12 ,,
		Average—7 mm.

It will be noticed that the amplitudes recorded in Table IV are about half those recorded on the two preceding tables, and indicate that the sources from which the signals were received were at distances appreciably greater than those of the previous sources, perhaps twice as great. It is reasonable to conclude that these signals came from sources in no way related to the conditions existing along the coast. On 5 days (17th September, 10th, 11th, 16th, 18th October) the coastal situation was such that definite "highs" were indicated off the coast, and on one day (17th October) there was no coastal variation in pressure, and on none of these days were signals received from the Atlantic Ocean.

INDIAN OCEAN SOURCES.

Depressions off the East Coast of South Africa are less easy to observe from Cape Town, since their effects are often masked by land storms. On 4 days (10th, 17th, 23rd, 24th September) definite "lows" were recorded on the meteorological maps off the coast of Natal and Pondoland. On all these occasions signals which could not be attributed to land sources were received on the Cathode Ray Direction Finder from these directions.

REDUCTION OF AMPLITUDES TO INPUT FIELD STRENGTH.

A land thunderstorm at a distance of 800 miles gave, on the average, an oscillograph deflection of amplitude 1 cm. In order to reduce this to the equivalent intensity in the same sense as that used by Munro and Huxley,† *i.e.* the field intensity of the continuous wave which will produce on the screen the same deflection as does the atmospheric, we proceeded as follows.

disturbances were passing along the S. and S.E. coasts. The same may apply to 1 of the 5 days in Table I (21st September) and to 4 of the 13 days in Table II (20th and 25th September and 12th and 15th October).

* 1 mm. = 102 μ volts/metre.

† Munro and Huxley, *loc. cit.*

The amplifier gain was determined with an A.C. 50 cycle input, and found to be $1{\cdot}0 \times 10^4$ or 80 decibels. Calculation from the frame constants previously given then yields an equivalent field intensity of 1020 micro-volts/metre for unit deflection. The corresponding figure obtained by the Australian writers is 1000 micro-volts/metre. As the above method of reduction is only approximate, the close agreement is fortuitous.

The Range in the Amplitude of Atmospherics from a Particular Source.

The question of the actual range in the amplitude of atmospherics from a particular thunderstorm is of some practical importance. In analysing the observations for this purpose we have found it desirable to omit consideration of all storms which gave maximum amplitudes on the screen less than 20 mm., in view of the possibility that very small deflections might have escaped notice. For 27 storms giving maximum deflections greater than this, the ratio of maximum to minimum amplitude has been determined, and a distribution table is given below.

Table V.

Range of Amplitude of Atmospherics from a Particular Source.

Ratio max./min. lying between .	0–1	1–2	2–3	3–4	4–5
Number of cases	0	3	10	5	9

It will be seen that the most frequent value for this ratio lies between 2 and 3. The few observations made at night indicate clearly a rise in the average amplitude of atmospherics from a particular source after dark by a factor of the order of two, but are insufficient in number for further discussion at this stage.

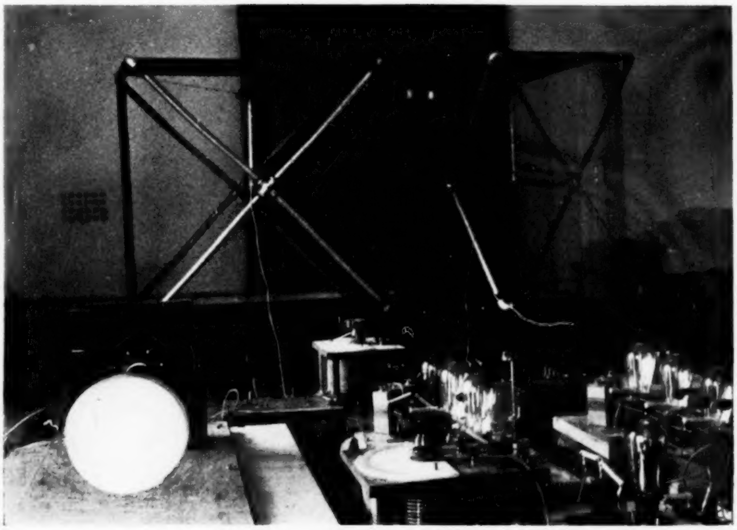
The investigations described in this paper were greatly assisted by the advice and co-operation of the staff of the British Radio Research Station, Slough, and, in particular, of the late Mr. J. F. Herd. We wish to thank Mr. Linton, of the University of Cape Town, for much valuable assistance, and the Government Meteorologists of the Union of South Africa and Southern Rhodesia for their interest and co-operation.

Summary.

Directional location of sources of atmospherics on a wavelength of 27·6 kilometres from a station in Cape Town has been carried out over a

period of 26 days in September and October 1935. Eighty-nine per cent. of the thunderstorms reported by the meteorological report network were correctly located in bearing. Fifty-three per cent. of the bearings over regions covered fairly satisfactorily by the meteorological network were definitely associated with thunderstorms. The results thus support the conclusion of Watson Watt and others that the lightning flash is the chief source of atmospherics.

Sources of atmospherics over the Indian and Atlantic Oceans are shown to be related to the presence of ocean depressions. The ratio of the extreme amplitudes of atmospherics from a particular source has a range of between 2 and 5. The sources observed ranged in distance from 350 miles to 1000 miles.



STUDIES IN SOUTH AFRICAN RICCIACEAE.

I. Three annual species: *R. plana* Taylor, *R. cupulifera* sp. nov., and *R. Curtisii* T. P. James.

By A. V. Duthie and S. Garside.

(With Plate VII and fifty-four Text-figures.)

(Read October 18, 1935. Revised MS. received February 13, 1936.)

1. Introduction.

Although the publication of Sim's "Bryophyta of South Africa" in 1926 has made the identification of local liverworts a far simpler matter than it was, the need for further study and more detailed descriptions of many species mentioned in the above work, as well as for accurate accounts of new forms, is apparent to all. Especially is this true of the Ricciaceae. With the exception of Dr. Sim's own collection, now the property of the Department of Agriculture, Pretoria, the family is very poorly represented in South African herbaria, and what specimens there are are often inaccurately named. This is not surprising, for the types of the older species are scattered in European collections, and so not readily accessible, and the material upon which many of the original descriptions were based was often very inadequate. Moreover, distinct species frequently grow intermixed in favourable localities, thus increasing the risk of confusion and the difficulty of accurate identification. Many important characters cannot be determined satisfactorily from dried material; and the need for careful study in the field, supplemented by comparison with forms from other parts of South Africa, and grown under varying conditions, can hardly be overestimated.

The genus is a large one, comprising about 200 species, and is well represented in sub-tropical regions with dry summers and winter rainfall. Sim gives brief descriptions of 14 South African species, but the total number is certainly far greater. On the Stellenbosch Flats alone 11 species occur, several of which are apparently undescribed. The authors of this

paper hope within the next few years to publish accounts of these and other South African species.*

Our thanks are due to the Keeper of Botany, British Museum, Mr. J. Ramsbottom, and to Dr. Cotton, the Keeper of the Herbarium at Kew, for permission to use the library and herbarium, and to Mr. C. Marquand for assistance in the examination of specimens and literature; to the Keeper of the Manchester Museum for permission to examine the *Riccia* collection, which incorporates the herbaria of Austen, Pearson, Carrington and Holt, and to Miss G. Wigglesworth, the Assistant Keeper of Botany: to the Secretary of the Linnean Society for help in the examination of the specimens of *Riccia* in the Linnean Herbarium; to Dr. I. B. Pole Evans for the loan of the *Riccia* collection belonging to the Cryptogamic Herbarium of the Department of Agriculture, Pretoria; to Dr. H. Weimarck for a set of dried specimens from Sweden; to Dr. F. McAllister and Dr. C. E. Allen for literature, and to the former for preserved thalli of *R. Curtisii* from Texas, as well as to many friends in this country who have kindly supplied us with living South African material.

The specific identification in certain cases is proving difficult owing to the inadequate material left to us by the earlier students of the group, though most of the older South African species have again been found by us, and fuller descriptions can now be given than was originally possible.

So far as our observations go, the limits of the majority of the South African *Ricciae* appear to be clearly defined, though the vegetative characters often vary greatly when grown under different environmental conditions, hence the desirability of study of the species in cultivation as well as in the field.

2. Taxonomic History of the Ricciaceae.

A hundred years have passed since J. B. W. Lindenberg (26) published his "Monographie der Riccieen" (1836), and during this period the discovery of alternation of generations, and the more detailed knowledge of structure and life-history obtained by improved technique have revolutionised our attitude towards these plants.

In the past hundred years much literature has accumulated dealing with the structure, life-history, cytology, and taxonomy of the Ricciaceae,

* The authors will welcome material from collectors in all parts of the country. When possible the plants should be sent fresh, wrapped separately in lead foil or tightly packed in small tins; but where this is not practicable they should be dried or preserved in alcohol. As spore characters are of great importance in separating species, fruiting material should be collected whenever available. Field notes on habitat, relative frequency, and appearance of the plants when fresh are also desired.

but for the most part only with reference to the European and North American representatives. Meanwhile little is known of the species of the Southern Hemisphere beyond a few superficial descriptions made from unsatisfactory and often incomplete herbarium material. This is all the more regrettable because there are clear indications that a more thorough knowledge of the southern species must have an important influence upon all future efforts to define the limits of genera and sub-genera, and our present classification, which is based almost entirely upon the European species, will undoubtedly be profoundly modified when the southern plants are better known.

The first account of the Ricciaceae is that given in 1696 by Ray (43) of a plant which he classifies with lichens, and describes as follows: "*Lichen minimus, foliis venosis, bifariam vel trifariam se dividendo progredientibus.*" It was considered by S. O. Lindberg (29) to be *Riccia glauca* L.

Following this, in those lists of plants, insects, birds, shells, and other curios (many from South Africa), which were compiled and published between 1695 and 1703 by James Petiver (41), a London apothecary, were two other species, "*Lactuca aquatica tenuifolia, segmentis bifidis*" (=*R. canaliculata* Hoffm., var. *B. fluitans* Rab.) and "*Lens palustris, Roris Solis foliis cordatis*" (=*R. natans* L.).

For brevity in what follows the modern names only are given, as determined by Lindberg (29), though the authors actually classified their plants under such genera as Lichen, Lichenastrum, Hepatica, and Ulva.

Dillenius (10) in 1718 gave an account of the plants now known as *R. sorocarpa* Bisch. and *R. canaliculata* Hoffm. var. *B. fluitans* Rab., and Vaillant (53) in 1723 recorded *R. crystallina* L.; Dillenius (11) in 1724 described *R. canaliculata* Hoffm. var. *B. fluitans* Rab., *R. sorocarpa* Bisch., *R. glauca* L., and *R. natans* L.; Vaillant (54) in 1727, *R. crystallina* L. and *R. glauca* L.; and Buxbaum (7) in 1728, *R. glauca* L.

Micheli (38), however, was the first botanist to give serious attention to the liverworts. He delimited and described many of the genera which are still in use to-day, and in his beautifully illustrated "Nova plantarum genera," published in Florence in 1729, he defined the genera *Marchantia*, *Hepatica* (=*Fegatella*, *Reboulia*, *Grimaldia*), *Targionia*, *Sphaerocarpos*, *Lunularia*, *Marsilea* (=spp. of *Pellia*, *Aneura*, *and Metzgeria*, including the plant later known as *Riccia fluitans* L. in the last genus); *Jungermannia* (=various genera of leafy liverworts), *Muscoides* (=*Porella*, *Frullania*, *Bazzania*), *Anthoceros*, *Blasia*, and *Riccia*.

His genus *Riccia* (named in honour of Count P. F. Ricci, a senator of Florence and patron of Micheli) was more comprehensive than it now is, because he included in it the plants later known as *Corsinia marchantioides* Raddi and *Tessellina pyramidata* Dum. That he recognised the latter

plants as distinct from the remaining species because their fructifications project from the thallus is quite clear from his subdivision of his genus *Riccia* into two "orders."

His "Ordo I. *Ricciae fructu e rimis foliorum surgente, et supra eorumdem foliorum planum se extollente,*" included *Corsinia* and *Oxymitra*, whilst "Ordo II. *Ricciae fructu in foliorum substantia contento*" included six species having fructifications enclosed in the thallus, all of which are still placed in *Riccia*, i.e. *R. crystallina* L.; *R. lamellosa* Raddi; *R. tumida* Lindenb.; *R. minima* Bellard; *R. cavernosa* Radd.; *R. glauca* L.; and *R. Michelii* Radd.

The above species are mentioned in those works dealing with cryptogams which appeared after the publication of "Nova plantarum genera," notably in "Historia muscorum" of Dillenius (12) in 1741.

In the first edition of the "Genera plantarum" (30) Linnaeus accepted Micheli's "*Riccia*," and included it in his "*Cryptogamia: Algae*," along with certain other genera, i.e. *Marchantia, Jungermania, Anthoceros, Riccia, Lichen, Lemna, Marsilea, Pilularia, Chara, Fucus, Ulva,* and *Conferva*. His conception of the structure of *Riccia* will be realised if we examine the definition of *Riccia* given in the above work. It is as follows:—

Riccia, Mich. Masculinus flos sessilis, Cal: nullus. Cor: nulla. Stam: Anthera subulata, truncata, sessilis, apice dehiscens. Feminibus flos in eadem (vel diversa Mich.) planta. Cal: vix ullus. Per: globosum, uniloculare. Sem: plurima.

It is evident that he attempted an interpretation of the structural features of the reproductive organs in terms of the flowering plants, so characteristic of the prevailing attitude of the period towards the *Cryptogamia*.

The account of *Riccia* was repeated verbatim in every succeeding edition of the "Genera plantarum" until the death of Linnaeus in 1778, but the eighth edition, 1789, edited by J. C. D. Schreber (31) contains a greatly amplified definition of the genus, based mainly on the researches of Hedwig (20) on the mode of reproduction of the *Cryptogamia*, though Schreber still retained the terminology of the flowering plants to designate the parts of the reproductive organs.

Linnaeus included only four species of *Riccia* in his "Species plantarum," 1st ed., i.e. *R. crystallina* (p. 1138), *R. minima, R. glauca,* and *R. fluitans* (p. 1139).

A recent inspection of the specimens of *Riccia* in the Linnean Herbarium has shown that there are no authenticated types of any of these species on the sheets, the specimens of *R. glauca* L. and *R. fluitans* L., which are the only species represented, have probably been added at a later date. There is no sheet written up by Linnaeus or by his son. This absence of

types is regrettable, because the "Species plantarum," 1st ed., has been adopted as the starting-point for the nomenclature of the Hepaticae, and also, now that we know that there may be considerable variation in spore markings, growth form, and even sex distribution in the "species," the absence of types renders it impossible to ascertain such details from plants named by Linnaeus himself.

Finally we must note that the generic characters are not given in the "Species plantarum," 1st ed. (1753); the genera included in this work are regarded as being validly published in the following year in the "Genera plantarum," 5th ed. (1754), where the characters of *Riccia*, as defined by Linnaeus, are given.

Before passing to the more modern treatments of the genus we must mention the large coloured plates illustrating the structure of several species of *Riccia* which were published by Schmidel (46) nine years after the publication of the "Species plantarum" of Linnaeus. In addition to figuring the organ of fructification as observed under low magnification, he illustrates and describes the important difference between species with a "solid" frond and those in which the frond has large air chambers, thus foreshadowing a distinction which was later to play such an important part in the grouping of the species.

The subsequent history of Micheli's *Riccia* now falls into three phases: the separation of certain species as distinct genera; the division of the remaining species into groups; and finally, when it was discovered that these groups or sections were not well founded, their re-absorption into more comprehensive sub-genera, a process having very varied results according to the knowledge of the several authors who attempted the task.

The disintegration commenced when Joseph Raddi (42) in 1818 separated the genera *Corsinia* and *Riccia* on very good characters. He considered *Corsinia* to be a distinct genus, mainly on the grounds that the sporangia are superficial, grouped in cavities of the thallus, and protected until maturity by a membranous involucre. On the other hand in *Riccia* the sporangia are more or less immersed in the thallus tissues, and are always without elaters. He recognised "*Riccia pyrimidata*" as being distinct from the remaining species, and placed it in the first of his three sub-divisions, "*Sporangia emergentia, videlicet quae super frondis attolluntur.*" The second division, "*Sporangia integre intra frondis substantium, nec visibilia nisi per frondis dissolutionem,*" contains *R. crystallina*, *R. lamellosa*, *R. ciliata*, *R. Michelii*, *R. glauca*, *R. minima*, and *R. cavernosa* (these are the actual names used by him), whilst *R. fluitans* is placed in the third section and designated "*Species dubii generis.*"

It was not long, however, before *R. fluitans* L., about which there was such ambiguity (much of which still remains), was separated as a distinct

genus. Braun (6) in 1821 made for its reception the genus *Ricciella*, but it should be noted that his definition was not that which is in use to-day. He defines *Riccia* as "*Capsula frondi immersa stylo emergente fugaci coronata*," and *Ricciella* as "*Capsula in inferiori frondis pagina sessilis, stylo destituta*." He includes in his *Ricciella* a floating and a terrestrial form. The air-chamber layer is not mentioned in Braun's definitions, his genera being distinguished by the position of the capsule and the presence or (supposed) absence of a "style" (archegonium neck).

B. C. Dumortier (14) in 1822 formulated an elaborate classification of plants, based on the method of fertilisation, vegetative parts, and germination, no portion of which appears to have survived, doubtless because it was founded upon a most inadequate knowledge of the plants concerned.

He appears to have been a little uncertain regarding the structure and exact position of *Riccia*, for he remarks: "Le genre *Riccia* qui fait aussi partie de cette famille a besoin d'être étudié de nouveau, on doit en former deux genres, savoir: 1e. *Riccia*, fruits enfonces dans le thalle; 2e. *Tessellina*, fruit sortant par une fente; on doit rapporter à ce dernier la *R. reticulata*, Poir. non Sw. = *Tessellina coriandri* nob. et la *R. pyrimidata* Willd. = *Tessellina pyrimidata*, nob."

No detailed description of his proposed new genus *Tessellina* is given; there is only a note on the position of the fruit, and he includes in the genus *R. reticulata* Poir. (=*Corsinia Raddi*), previously separated by Raddi as a genus distinct from *Riccia*.

Howe (21) has recently discussed whether the validity of the name *Tessellina* Dum. is established on such a meagre description. He points out that *Riccia reticulata* Poir. is *Corsinia marchantioides*, for which a genus had already been made by Raddi, and says: "It is scarcely open to doubt that it was Micheli's conspicuously reticulate or tessellate figure of the thallus of *Corsinia* and Micheli's diagnosis . . . that suggested to Dumortier the generic name *Tessellina*." The second of the two species *R. pyrimidata* Willd. is considered to be a true *Riccia* which was collected by Willdenow in the vicinity of Halle, and therefore cannot be the *Tessellina* of modern authors, because the latter plant does not occur in Germany.

Thus the genus *Tessellina* of Dumortier originally included two plants, neither of which is the *Tessellina* of modern authors, and as there were already genera adequate for their reception, the name is invalid. The valid name *Oxymitra* was adequately published seven years later by Bischoff (3).

In 1828 Corda (8) in his "Genera Hepaticarum," distinguished the two genera, *Corsinia Raddi* and "*Rupinia Linn. emend,*" and in the latter genus placed *Rupinia pyrimidata* Corda (=*Oxymitra* Bisch.). *Rupinia*

L. f. (Supp. Sp. Pl., p. 69, 1781) is, however, one of the Marchantiaceae, and a synonym of *Aytonia*.

In Ricciaceae Corda placed two old genera, *Riccia* Mich. and *Ricciella* Braun, along with a new genus *Ricciocarpus*. The description of the new genus (p. 651) is very inadequate, being "*F. Recept. cavum fronde immersum, dein secedens. Capsula O?—Semina aspera. R. natans* (*R. Linn.*)." Unless the genus had been typified it would be impossible to decide which plant was intended, because no precise character is given by which the new genus can be distinguished from *Riccia*. It appears that the characters which at a later date became associated with *Ricciocarpus* Corda have been gradually added by those authors who have had occasion to use the genus, so that ultimately [see Schiffner (45), Macvicar (36)] it was considered to differ from *Riccia* in having the archegonia surrounded by a rudimentary involucre, antheridia situated in a furrow along the centre of the thallus, the presence of air-pores surrounded by special cells, and ventral scales arising in several transverse rows.

However Garber (17), and later Lewis (25), in 1906 demonstrated that there is no rudimentary involucre surrounding the archegonium, and the other characters supposed to be peculiar to *Riccciocarpus* are now almost all known to exist in species which, from other considerations, are better placed in *Riccia*.

It appears that a superficial knowledge of the structure of *R. natans* L., and of the extra-European species of *Riccia*, were the causes which brought about the separation of the genus *Ricciocarpus*, and it will be observed in what follows that similar causes have been at work in determining the division of *Riccia* into sub-genera.

Bischoff (4) in 1835 made the first attempt to divide the genus *Riccia* Mich. (*sensu stricto*) into sub-genera. Although he described only a few species, he examined these in considerable detail. Recognising *Corsinia* and *Oxymitra* as distinct genera, he divides *Riccia* into three sections: "*Sectio* 1. *Ricciae verae* S. Lichenoides. *Fructus plerumque in pagina frondis superiore protuberantes et illa fatiscente supra prorumpentes.*" This first section is subdivided into "*Fronde margine glabra,*" with *R. sorocarpa* and *R. glauca*, and "*Fronde margine ciliata*" with *R. ciliata* and *R. Bischoffii*.

Section 2 is made for *R. fluitans* L., which is defined as follows: "*Sectio* 2. Ricciellae. *Fructus in pagina frondis inferiore protuberantes et illa fatiscente subtus prorumpentes.*" The new name *R. eudichotoma* is given, with two varieties (*a*) *fluitans* and (*b*) *canaliculata*.

Finally, "*Sectio* 3. *Ricciae dimidiantes. s.* Hemiseumata. *Fructus in neutra frondis pagina protuberantes, demum ob discessum frondis longitudinalem in sulco intermedio denudati,*" is made for *R. natans* L.

Bischoff's work was closely followed by that of J. B. W. Lindenberg,

whose "Monographie der Riccieen" (26), 1836, was the first attempt to give a complete account of the Ricciaceae of the world. At this period the limitations of the family were not those of the present day. Lindenberg included in the Ricciaceae the genera *Riccia*, *Oxymitra*, *Corsinia*, and *Sphaerocarpus*, but remarked that the genera *Ricciella* (*R. fluitans*) and *Ricciocarpus* (*R. natans*) were insufficiently well known as regards their fruits, and therefore he does not give them generic rank.

Corsinia and *Sphaerocarpus* were included in the Ricciaceae because they were supposed to have the character he attributes to the family "*Sporangium . . . irregulariter rumpens. Sporae elateribus destitutae.*" In both of these genera the foot and the sterile cells between the spores escaped detection, though it must be borne in mind that in the older works the term "elater" always signified a cell with spiral or annular thickenings on its walls. For the genus *Riccia* he made no sub-genera, and his key to the twenty described species is based primarily upon the presence or (supposed) absence of ventral scales.

Bischoff, when dividing *Riccia* into sub-genera, used (as all his predecessors) characters derived from the position of the capsule in the thallus and the direction and mode of liberation of the spores, but in the next treatment of *Riccia* we detect a change, and for the first time the structure of the air-chamber layer was taken into account in the delimitation of the sections.

In 1838 Nees (39), in his work on European liverworts, accepted Bischoff's three sections, gave them an amplified diagnosis, and added a fourth section, "*Spongodes.*" These sections were subsequently used by Sim (48) in his treatment of the South African species, and it will be well therefore to examine the definitions as given by Nees. They are as follows:—

"*Lichenoides.*—Frons solida (*i.e.* cavitatibus aëreis haud intercepta). Fructus plerumque in pagina superiori frondis protuberantes et illa disrumpente aut fatiscente demum denudati. Terrestres, arcte repentes."

This group includes eleven species, e.g. *R. glauca* L.

"*Spongodes.*—Frons cavernosa, laxa. Fructus latentes aut in pagina superiori frondis protuberantes illaque fatiscente demum denudati. Terrestres, limicolae, arcte repentes."

Here are two species only, *R. crystallina* L. and *R. bullosa* Link.

"*Ricciella.*—Frons cavernosa. Fructus in pagina frondis inferiori protuberantes et illa fatiscente subtus prorumpentes. Natantes, aut in limo molli repentes."

Here are three species, *R. Hueberiana* Lind., *R. fluitans* L., and *R. nodosa* De C.

"*Hemiseuma.*—Frons cavernosa. Fructus in neutra frondis pagina

protuberantes, demum ob frondis incisuram profundis penetrantem in sulco medio denudati, geminati. Natantes."

Only one species, *R. natans* L.

These sections are based mainly on two characters, the nature of the air-chamber layer and the direction of liberation of the spores in relation to the thallus surfaces. The new group "Spongodes" was evidently made to accommodate the species having large air-chambers, but with dorsal liberation of the spores, i.e. *R. crystallina* L. and *R. bullosa* Link. It is surprising to find the latter species, which is a South African plant, in a work on European liverworts, but it was included because it was also supposed to grow in Spain. Nees drew his description from sterile South African material, so that he could not have known the direction of liberation of the spores. The Spanish plant was subsequently shown to belong to the genus *Exormotheca*.

The above sub-genera of Nees were used without change to classify the species of *Riccia* included by Gottsche, Lindenberg, and Nees in their "Synopis Hepaticarum" (1844, p. 47) (18), which constitutes the second attempt at a monograph of the genus.

Researches concerning the development of the thallus, reproductive structures, and life-history of *Riccia* now began to be made. Unger (51) in 1837 first observed the motile antherozooids of a liverwort (*Marchantia*), and published in 1839 (52) an account of the reproductive organs of *Riccia*. Twelve years later Hofmeister's epoch-making work, the "Vergleichende Untersuchungen," 1851 (including an account of *Riccia glauca*), appeared; a work which for the first time made clear the true significance of the sporogonium and spores in the life-history. This was soon followed by a series of detailed studies, beginning with the work of L. Kny (24), 1867, on the development of the thallus and reproductive organs; studies which have been continued by various botanists up to the present time.

The curious attempt which was made to isolate *Riccia Curtisii* (Austin) James as the type of a new genus now calls for attention.

This plant was first published by T. P. James in 1869 from Austin's manuscript. Austin, on account of the permanent adherence of the spores in tetrads, and the supposed resemblance of the thallus to *Sphaerocarpos*, thought it to be intermediate between this genus and *Riccia*, and made for it a new genus, *Cryptocarpus*.

In 1874 Lindberg (28) pointed out that *Cryptocarpus* was already in use for a genus of Chenopodiaceae, and proposed the name *Thallocarpus*. An entirely new and unnecessary name, *Angiocarpus*, was proposed by Trevisan (50) in 1877, but he gave no precise definition. The genus *Thallocarpus* was still maintained by Schiffner (45) in his treatment of the liverworts in Engler and Prantl's "Pflanzenfamilien," 1909, where he placed

it along with *Sphaerocarpus*, in the *Jungermanniaceae anakrogynae*. A subsequent re-examination of the plant by McAllister (34) showed that it should be included in the Marchantiales, and it is now usually considered merely as a somewhat aberrant *Riccia*.

In 1879 Lindberg (27) introduced a group name (*Euriccia*) which is still in use, although its definition has been altered by subsequent authors. In his treatment of the Bryophyta of Scandinavia he divided the genus *Riccia* into two sub-genera. (A) *Ricciocarpus* (Corda) Lindb., including only *R. natans* L., and (B) *Euriccia* Lindb., which was subdivided into several groups: (*a*) *Terrestres* Lindb., with e.g. *R. sorocarpa*, *R. glauca*, *R. ciliata*, etc.; (*b*) *Spongodes* Nees, with *R. crystallina* L.; and (*c*) *Ricciella* (Braun) Bisch., with *R. Huebeneri* and *R. canaliculata*, with var. b. *fluitans*.

The modern grouping of the species of *Riccia* into two sections, those with a "solid" thallus, *i.e.* with the chlorenchyma provided only with minute perpendicular air-canals, and those with a chambered thallus, *i.e.* the chlorenchyma with wide air-chambers separated by plates of green cells, and usually opening to the exterior by more or less well defined air-pores, was first made by Stephani (49) in 1898, in his monograph of *Riccia*. He does not use the term *Euriccia* for the "solid" forms, but groups under the heading "*A. Riccia*," the 83 species of this type which he describes. The species with large air-chambers, of which he gives 45, are grouped under the heading "*Riccia B. Ricciella*." Here for the first time the name *Ricciella* is used with an entirely different meaning from that originally given to it in 1821 by A. Braun, who applied the name only to *R. fluitans*, defined it as a genus having the capsule situated on the ventral surface of the frond, and made no mention of the structure of the air-chamber layer.

Authors following Braun had also used it in this very restricted sense, until Stephani instituted his sweeping change. Stephani's monograph was the first comprehensive account of the genus; previous attempts at monographic work [Lindenberg (26), Gottsch, Lindenberg and Nees (18)] included little more than the European species.

Stephani, who had the opportunity to examine and compare species from all parts of the world, showed that he considered the sections already instituted by previous writers unsuitable for a comprehensive classification. He divided the species into 13 small groups, to which group names were not given, and which are based mainly on the texture, thickness, marginal and surface features of the thallus (*i.e.* entirely on vegetative characters). Eight of these groups are placed under *A. Riccia*, the first three of these being "*Ciliatae*," and the remaining five "*Inermes*." Under *B. Ricciella* are the remaining five groups. The grouping used by Stephani is an artificial one, but served its purpose for the classification of the herbarium material with which he had to deal.

Stephani's definitions of the two great sections, though included in the introduction, and not in the descriptive text, are very clear (49, p. 311). He says, "Die chlorophyll-führende dorsale Laubschicht wird, wie bekannt, bei der Gattung *Riccia* aus langen, aufrechten, saülenförmigen Lamellen gebildet, die aus Zellreihen bestehen und unter sich der Länge nach verwachsen sind; von ihnen schliessen immer je vier einen engen Kanal ein. *Ricciella* unterscheidet sich hiervon durch flächenförmige Lamellen, die weite Luftraüme begrenzen."

He was the first to discover that there exist transitional forms between these two types of thallus, for he points out that *R. vesiculosa* C. et R. from Australia has air-chambers bounded by 8 vertical rows of cells (the number varies between 7 and 9), the significance of which he was quick to realise, for he says (p. 376): "Es ist kaum berichtig, die Gattung in 2 zu spalten, wo, wie diese Pflanze zeigt, Ubergänge vorhanden sind." This discovery of transitional forms is probably the reason why Stephani refrained from making sub-generic names for the sections, in the confident manner of numerous other authors who had to deal only with the few species of a local flora. Indeed, he says (p. 312), "Ein solche Ubergangsform . . . macht die Scheidung der Gruppe in zwei Gattungen, Riccia und Ricciella, hinfällig; die Trennung habe ich daher nur aus praktischen Rücksichten in der Form von Unterabtheilungen durchgeführt."

It was a local flora which Boulay (5) described in 1904 when he subdivided the genus *Riccia* into three sub-genera, *Ricciocarpus* Corda (*R. natans* L.), *Ricciella* Bisch. (*R. crystallina* L., *R. Hueberiana* Lind. and *R. fluitans* L.), and *Euriccia* Lindb. (14 species, including *R. sorocarpa*, *glauca*, *nigrella*, etc.).

Although Boulay cites Lindberg as the author of *Euriccia*, his definition is very different from that of the original author. Lindberg's *Euriccia* included all the species, whether "solid" or with air-chambers, except *R. natans* L.; Boulay's *Euriccia* is defined in the sense now in modern use as having "l'appareil chlorophyllien, . . . sur une coupe transverse se montre formé de lames verticales nombreuses (30–60) composées d'une assise de cellules superposées vertes; la cellule terminale ordinarement plus grande représente l'epiderme; ces lames verticales, les unes longitudinales, les autres transverses, se relient, 4 par 4, pour constituer des colonnes creuses dont les cavités consitiuent autant de chambers à air." Nothing is said about the direction of dehiscence of the sporangium. *Ricciella* is defined as "texture des frondes spongieuse, avec grandes chambres à air, appareil sporifère s'ouvrant du côte ventral."

The old definition relating to the direction of dehiscence of the sporangium is retained as a character of *Ricciella*, though this is certainly incorrect for *R. crystallina*, which was included by Boulay in this section.

In 1909 Schiffner (45), with considerable justification, reverted again to the older treatment of the genus, dividing *Riccia* into *Euriccia* Lindb. (*R. glauca*, *R. sorocarpa*, *R. crystallina*, etc.), and *Ricciella* with only *R. fluitans* L. His *Euriccia* was like that of Lindberg, but with the separation of *Ricciella* as a sub-genus. *Ricciocarpus* Corda and *Tessellina* Dum. he considered to be good genera.

It is unnecessary to review the treatment of *Riccia* in subsequent works, with the exception of that of Sim (48). The classifications used have been variants of those already described, but adapted to the needs of local floras, and no monograph of the species of the world has appeared since the work of Stephani.

An attempt to separate a species of *Riccia* as a distinct genus was made in 1919, when Douin and Trabut (13) described certain features of *Riccia perennis* Steph., a tuber forming species from Algeria, which they had under cultivation. They pointed out that the structure of the thallus with its well defined air-pores, archegonia situated singly in wide open pits in the median line, and male ostioles each surrounded by an involucre-like ring of short papillae, might entitle the plant to generic rank. They therefore propose the name *Riccina*, and suggest that it is a genus intermediate between *Riccia* and *Corsinia*. However, as the sporogonium and spores are unknown, and the thallus for the most part presents features which occur in some South African *Ricciae*, it is extremely doubtful whether the plant is entitled to generic rank. It should be retained in *Riccia* until its complete life-history is known.

The final scheme of classification of species of *Riccia* which we shall consider is the one used by Sim (48) in 1927 in his grouping of those South African species which were known to him.

Unfortunately he gives no citation of authorities for the five sub-genera under which he grouped his plants, but it is clear from the definitions given and from the species included, that four of these groups have been used before, and only one (*Favoides*) is new, having been made for the reception of two species, *R. bullosa* Link. and *R. Garsidei* Sim; the first an old species, formerly included by Nees (39) in "*Sponogodes*," the latter a new species first published by Sim in the work under discussion.

The following sub-genera are used by Sim:—

1. LICHENOIDES. Bischoff in Acta Acad. Caes. Leop., xvii, p. 1053, 1835.
2. FAVOIDES. Sim in Trans. Roy. Soc. S. Africa, x, p. 8, 1926.
3. SPONGODES. Nees in Nat. Eur. Leberm., p. 391, 1838.
4. RICCIELLA. (A. Braun in Flora, i, p. 756, 1821, pr. gen.), Bischoff in Acta Acad. Caes. Leop., xvii, p. 1068, 1835.
5. RICCIOCARPUS. (Corda in Opiz. Beitr., p. 651, pr. gen.) Lindberg in Musci Scand., p. 2, 1879.

The most important character given by Sim as a distinction between *Favoides* and *Spongodes* is that in the former the thallus has one layer of air-cavities only; in the latter the thallus has numerous large superimposed air-cavities, separated by walls which are one cell in thickness.

In transverse section the species which Sim places in *Spongodes* certainly may appear to have superimposed air-chambers, but the effect is due to the very oblique angle which each chamber makes with the basal line; actually the air-chambers are formed at the apex in a single layer, and remain so. Thus the distinction made by Sim breaks down, and the group *Favoides*, in this respect at least, cannot be maintained. The remaining groups, *Lichenoides*, *Ricciella*, and *Ricciocarpus* are very accurately used by Sim as originally defined by their respective authors.

The above account of the Ricciaceae omits certain synonyms which have had no permanent effect upon the classification of the family; these are *Riccardius* Gray, 1821 (*Riccia* L.), *Pycnoscenus* S. O. Lindb., 1863 (=*Oxymitra* Bisch., 1829), *Hemna* Raf., 1817, and *Salvinella* Huben., 1834 (=*Ricciocarpus* Corda, 1829), *Cronisia* Berk., 1857, and *Carringtonia* S. O. Lingb., 1868 (*Cronisia paradoxa* Berk., 1857=*Riccia paradoxa* Wils. et Hook., 1844. Stephani considers this to belong to the Marchantiaceae, because the sporogonium has a foot, the capsule wall is of one layer of cells with semi-annular thickenings).

In reviewing the history of Micheli's "*Riccia*" the influence of a few structurally somewhat isolated species upon the classifications used by various writers is very evident, these species being at once elevated to generic rank, as soon as their structural peculiarities became better known. It is a remarkable fact that all the species thus raised to genera have the "air-chamber" type of thallus, i.e. *Corsinia*, *Ricciella*, *Oxymitra*, *Ricciocarpus*, *Thallocarpus*, and *Riccina*.

Until comparatively recent years, the classification of the Ricciaceae has been based almost entirely upon a knowledge of European species. Stephani was the first with adequate material for study who attempted to formulate a classification to comprise the species of the world, and his is admittedly an artificial one. A natural classification must be based upon a more detailed knowledge of anatomy and development than we now possess; only a few of the European and North American species have been intensively examined, and of the life-histories of the numerous species of the Southern Hemisphere we have no published accounts.

The recent work of K. Meyer (37), however, gives some indication of the direction in which a search for natural affinities might be made. Meyer points out that in the higher Marchantiales, e.g. *Plagiochasma*, *Grimaldia*, *Reboulia*, *Fegatella*, *Fimbriaria* and others, the early divisions of the egg-cell to produce a row of cells, the "filamentous embryo," is to be considered

primitive, not only for Marchantiales, but for the Bryophyta, brown algae, and many other plant groups. On the other hand, the "quadrant type" of embryo found in *Marchantia*, *Preissia*, *Astroporeae*, *Corsinia Oxymitra*, and *Riccia* can be interpreted as derived by modification of the "filamentous" type. In some species the condition is not fixed, and both types may be found, e.g. *Marchantia polymorpha* and some species of *Riccia*. Although simple in structure the sporogonium of *Riccia* is not considered by Meyer as a "primitive" type but as a specialised structure, even in some respects progressive, *e.g.* the nutritive "tapetum" formed by disintegration of the sporogonium wall, a feature peculiar to this genus.

Earlier investigations by other workers have indicated that the thallus structure in *Riccia* can be considered as derived by simplification from more elaborate marchantiaceous forms. We therefore make the suggestion that the Ricciaceae may be a polyphyletic group, derived along several lines of descent from the higher Marchantiales, and the search for affinities will assume a very different aspect. The section of *Riccia* containing the species with air-chambers may include many lines of descent from the higher marchantiaceous forms, each of these leading in turn to species with the "solid" type of thallus. With the more "reduced" forms the indications of affinity may be insufficient to enable us to make an exact decision.

Full details of the structure and life-history of most of the species of *Riccia* will be required before a natural classification into sub-genera can be made, and it is impossible at present to attempt such a classification because the necessary data are not available.

The authors therefore present these studies in the hope that they will be acceptable, not only as an account of the South African species, but as a contribution towards a fuller knowledge of the group.

3. Notes on the Thallus and Spore Structure.

The gametophytes in this genus are annual or perennial and dichotomously branched, the adult thallus having frequently the form of a complete or incomplete rosette.

As seen in vertical section the thallus shows an upper, photosynthetic zone of green tissue, and a lower zone of compact, more or less colourless, cells serving for food storage. In the majority of species the green upper zone consists of pillar-like vertical rows of cells separated by narrow air-spaces, the terminal cells of these vertical rows being usually larger than the rest, and devoid of chlorophyll (fig. 2). In other species the green zone consists of one-layered cell plates, limiting polyhedral air-chambers, which are roofed over by an epidermis (fig. 3). These chambers are usually arranged in a single series, and the roof above each is perforated by a

simple air-pore. The lower epidermis bears smooth and tuberculate rhizoids and one-layered ventral scales; the latter are usually formed singly behind the growing point, but become split in the middle by later thallus growth, thus giving rise to two lateral rows of scales. The sex-organs, which are found on the same or on distinct thalli, arise singly

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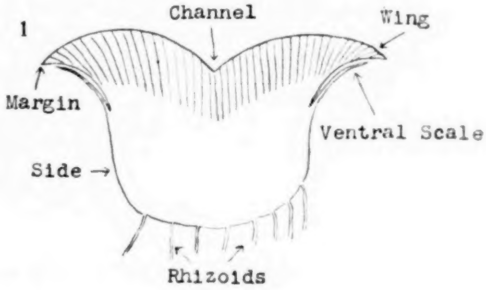

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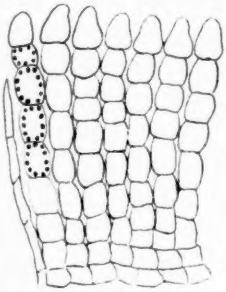

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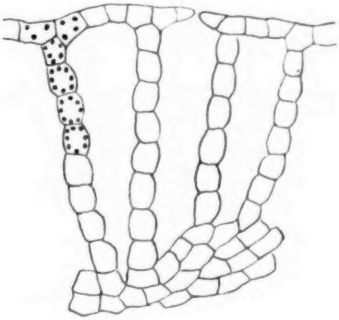


Fig. 1.—Diagrammatic transverse section through a thallus lobe.
Fig. 2.—Vertical rows of photosynthetic cells separated by narrow air-spaces.
Fig. 3.—Air-chambers separated by plates of photosynthetic cells.

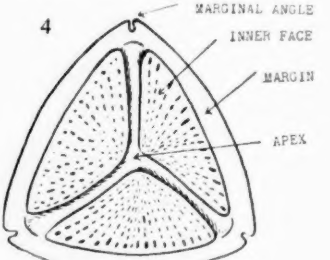
from the dorsal surface and soon become deeply sunk in the thallus. The sterile cells surrounding each antheridium are usually developed above into a chimney-shaped ostiole, through which the sperms are later ejected. The fertilised egg segments to form a mass of spore-producing cells surrounded by a single layered capsule wall. During the development of the embryo the wall of the archegonial venter becomes two-layered, the outer layer being rich in chlorophyll. Both capsule wall and inner layer of the venter disintegrate before the spores reach maturity.

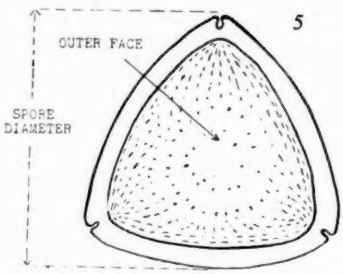
The mature spore has a thick and usually brown wall with characteristic

markings, giving important diagnostic characters which in the past have too often been neglected or only superficially observed.

In herbarium material the spore is usually the only part of the plant which has retained its characteristic form, hence the importance of spore size and markings for taxonomic work.

In order to facilitate a description of the spores of the various species it is necessary to define precisely the terms which will be used. The





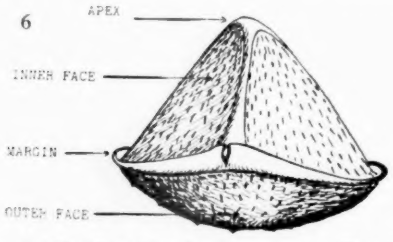


FIG. 4.—The three inner faces. FIG. 5.—The outer face.

FIG. 6.—Spore in profile.

spores of *Riccia* are formed in tetrads, and each spore is roughly tetrahedral in form, and has an "outer face" and three "inner faces."

The outer face, which is usually very convex, is marked with ridges, papillae, spines, or a combination of these, forming a distinctive pattern. The three inner faces of the spore, which are triangular in outline, are separated from the outer face by a more or less prominent equatorial girdle or rim, here called the "margin," and from each other by three ridges, which extend from the "apex" of the spore to the "marginal angles."

The inner faces are either plane surfaces or more or less convex, and as a rule have less elaborate markings than the outer face.

The three suture lines extending from the apex to the marginal angles form the "triradiate marking."

The most important spore measurement is the "spore diameter," which is the measurement across the outer face, taken from one of the marginal angles to the middle of the opposite margin. This measurement always includes the margin itself. In some cases in which the margin is very broad or expanded into a wing its width is stated separately.

4. General Observations on the Three Annual Species.

The present paper deals with three common annual species, two of which are widely distributed in South Africa. One of these, *R. plana*, has been previously recorded only from West Australia; another, *R. Curtisii*, is fairly abundant in parts of America, but has not hitherto been known to occur in South Africa; while the third, *R. cupulifera*, is here described as new. *R. plana* is monoecious; the other two are dioecious. All three belong to the "*Ricciella*" section of the genus, characterised by the presence of air-chambers separated by plates of chlorophyll-containing cells in the upper zone of the thallus; but differences in texture and colour serve as valuable aids in distinguishing the species in the field. The air-chambers in all three species are apparently strictly uniseriate, though vertical sections across the thallus often give a false impression of secondary partition of the chambers resulting from their inclination towards the margins or growing point.

In the Stellenbosch district as well as in other localities these three species often grow intermingled and are liable to be confused, hence they are here described together in order that their distinguishing characters may be clearly brought out. Sim (48), judging from his description and figures in the "Bryophyta of South Africa," has apparently included plants belonging to the three species here discussed under the name *R. crystallina*. In favourable situations one or more species may appear in great numbers, carpeting the soil with rosettes and in places forming a dense mat of overlapping thalli of varying size and shape. While the dorsal surface of isolated thalli is usually horizontal, repeated division may cause a lateral overgrowth of some of the lobes of old, luxuriant rosettes. Adult thalli of *R. cupulifera* and *R. Curtisii*, kept moist in a covered glass dish in the laboratory for five weeks, were found to have developed numerous erect lobes from the margin, and also from the dorsal surface. Some of the smaller of these appeared to have arisen from single thallus cells. These adventitious lobes have not been noted in field material, and it is doubtful whether they ever serve normally for vegetative reproduction.

As in other species of the genus the outer persisting layer of the venter forms within it a large quantity of chlorophyll, and doubtless serves as an efficient photosynthetic organ during the development of the enclosed

sporophyte. In living plants this character is a valuable aid in the determination of the sex of the thallus.

The capsule wall disappears relatively early in all three species. In *R. cupulifera* and *R. plana* no definite wall has been noted at the time of the rounding off of the spore mother-cells.

Although in the Stellenbosch district, with its well-marked rainy season, ripe spores are found as a rule from the end of June to the end of September, in the Knysna district both *R. plana* and *R. Curtisii* have been found in fruit during the month of January.

In *R. cupulifera* the still living tissue of the thallus shrinks away from the mature sporophyte, leaving a smooth-walled, bowl-shaped depression, at the bottom of which the spores are set free by the early disintegration of the venter. It is because of this character that we have given the name *R. cupulifera* to the species. In *R. plana* the mature sporogonia are deeply embedded in the relatively compact tissue of the living thallus, and are usually invisible from above, though very conspicuous from below. The liberation of spores from the dorsal surface has been observed in South African material of *R. plana* and *R. Curtisii*, especially in thalli which have become waterlogged. The removal of the upper layer of thallus tissue from above the sporogonia sometimes results from the attacks of minute forms of animal life such as insect larvae. More frequently the thallus dries out before the spores have been shed, with the result that their liberation is effected by the gradual disintegration of the thallus as a whole. That spore-distribution in all three species is often imperfect is indicated by the frequent occurrence of masses of small thalli which have developed from the entire contents of one or more sporangia. In all three species rain and the activities of small animals are largely responsible for the local distribution of the spores, though over larger areas wind is a contributing factor when the thalli are dry and disintegrating.

The spores of *R. Curtisii* adhere in tetrads, while those of *R. plana* and *R. cupulifera* separate at maturity. In the Stellenbosch district germination begins soon after the early winter rains, and may continue over a long period. The length of time required for the germination of the spores appears to vary with their age and past history. In some cultures of *R. cupulifera* germination was found to begin in less than a fortnight.

In each of the species of *Riccia* described in this paper the spore germinates from the convex outer face, a peculiarity which has been observed in a number of other South African species, and seems likely to prove constant in the genus. Pandé (40) has recently recorded it for an Indian species, *R. sanguinea*; but it is noteworthy that in other published papers which refer to spore germination in *Riccia*, including that of Fellner (16) on

R. glauca, no mention appears to be made of the exact position of the germ tube, nor do the figures of germinating spores make this point clear. In single culture, considerable differences have been noted in the length of the germ tube and in the time of development of the first rhizoid.

So far as has been observed each of the three species described in this paper depends entirely on the spores for propagation and survival.

A fungus, *Olpidiopsis Ricciae* du Plessis (15), is often present in both smooth and tuberculate rhizoids of all three species.

5. Descriptions of Species. Biological and Historical Notes.

Riccia plana Taylor.

R. plana Taylor, The London Journal of Botany, v, p. 414, 1864.
„ „ Gottsche, Lindenberg et Nees. Synopsis Hepaticarum, p. 794, 1847.
„ „ Stephani, Syn. Hep. Bull. Herb. Boiss., vi, p. 368, 1898.

Figures.—Figs. 7-20 and Pl. VII, fig. 3.

Type.—Swan River, Australia. Leg. James Drummond, sine num. 1843.

Exsic.—Duthie 5006. Stellenbosch, on and near cultivated ground. Aug.-Sept. 1929–1932. Duthie 5192. Stellenbosch, on and near cultivated ground. Aug.-Sept. 1933–1934. Duthie 5052. Stellenbosch, side of pond, University garden. April 1930. Duthie 5216. Stellenbosch, surface of moist flower-pots, University greenhouse. Sept. 1934. Duthie 5306. Rosebank, garden ground. Aug. 1935. Duthie 5315. Kleinberg, Tulbagh, along irrigation furrows. Oct. 4, 1935. Duthie 5309. Knysna, garden ground. Aug. 1935. Duthie 5313. Orange River near Upington, on alluvial soil. Sept. 1935. Duthie 5145. Middelburg, C.P., alluvial mud, side of stream. July 1931.

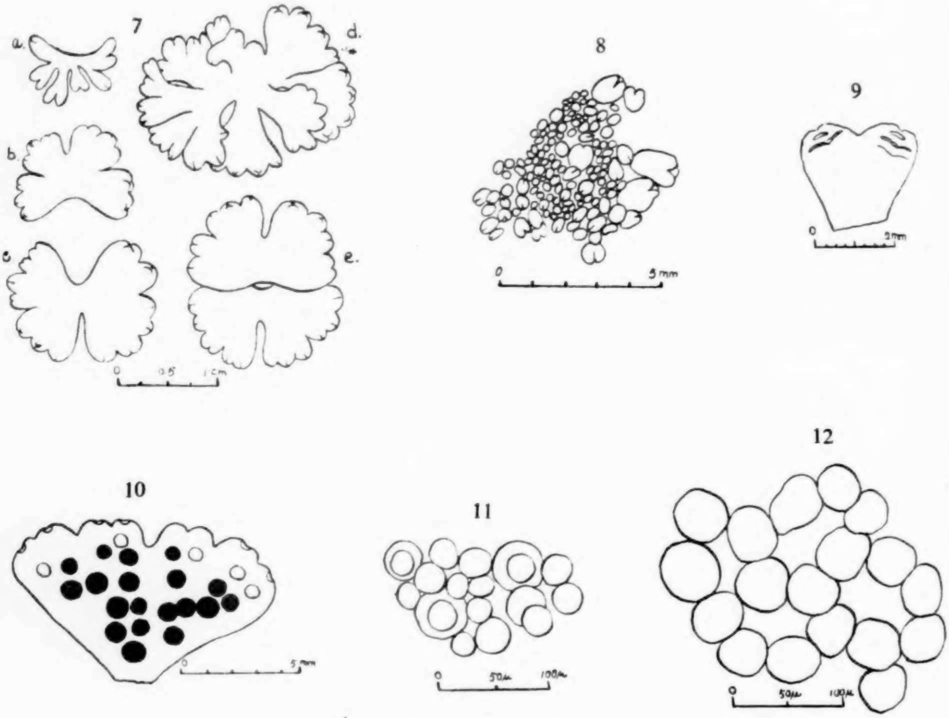
Cryptogamic Herbarium, Pretoria. 68. Fauresmith, O.F.S., moist, shady spot on hill slope. Leg. C. A. Smith, Sept. 1925.

Cryptogamic Herbarium, Pretoria. 1069. Fauresmith, O.F.S., moist, shady spot on hill slope. Leg. C. A. Smith, April 1925.

Monoecious.—In isolated or crowded complete or incomplete rosettes up to 2 cm. diam., very occasionally reaching a diameter of 2·5 cm., usually grey-green in colour, never purple or brown-purple, concolorous, upper surface markedly crystalline with abundant, turgid, light-reflecting cells, which obscure the simple air-pores. *Thallus* lobes typically obcuneate, several times dichotomously branched, with crowded segments. Texture of young thallus compact, dorsal surface of older parts showing a tendency to become pitted through great enlargement of the air-pores. Transverse section of older part of thallus about 1 mm. thick, but varying according to conditions of growth. The dorsal and ventral surfaces nearly flat and parallel. Ventral scales exceedingly small and difficult to detect. *Antheridial* ostioles conical, colourless and transparent, after discharge of sperms, lengthening to about 200 μ above surface of thallus. *Archegonial* neck 160 μ to 260 μ long, the upper part collapsing after fertilisation, the lower becoming brown and rigid. *Spores* light or medium brown, outer face 60–80 μ diameter, very convex, regularly reticulate with low walls (sometimes incomplete), separating the areolae, of which there are 6 to 8 across the spore diameter, the areolae 7 to 10 μ wide. Flattened spines, with truncate, entire, or shortly bifid or trifid apices arise from the reticulum, chiefly from its nodes. In profile the convex face shows 20 to 25 spines. *Spore margin*

expanded into a narrow wing 4 to 6 μ wide, its outer edge finely erose, the marginal angles entire or frequently with one oval or irregular perforation or slit. *Inner faces* with walls of the reticulum as a rule very imperfect, and with short, truncate, usually simple spines arising from them. Triradiate marking inconspicuous, consisting of irregular ridges becoming imperfect towards the spore margin and the apex.

The above description is based on Duthie 5006.



R. plana, figs. 7–12.

FIG. 7.—*a–e*, thallus forms. FIG. 8.—Part of cluster of small thalli.

FIG. 9.—Ventral surface of young lobe showing scales.

FIG. 10.—Ventral surface of thallus showing distribution of sporangia.

FIG. 11.—Dorsal surface of young thallus lobe, with turgid, light-reflecting cells.

FIG. 12.—Horizontal section through photosynthetic tissue of young thallus.

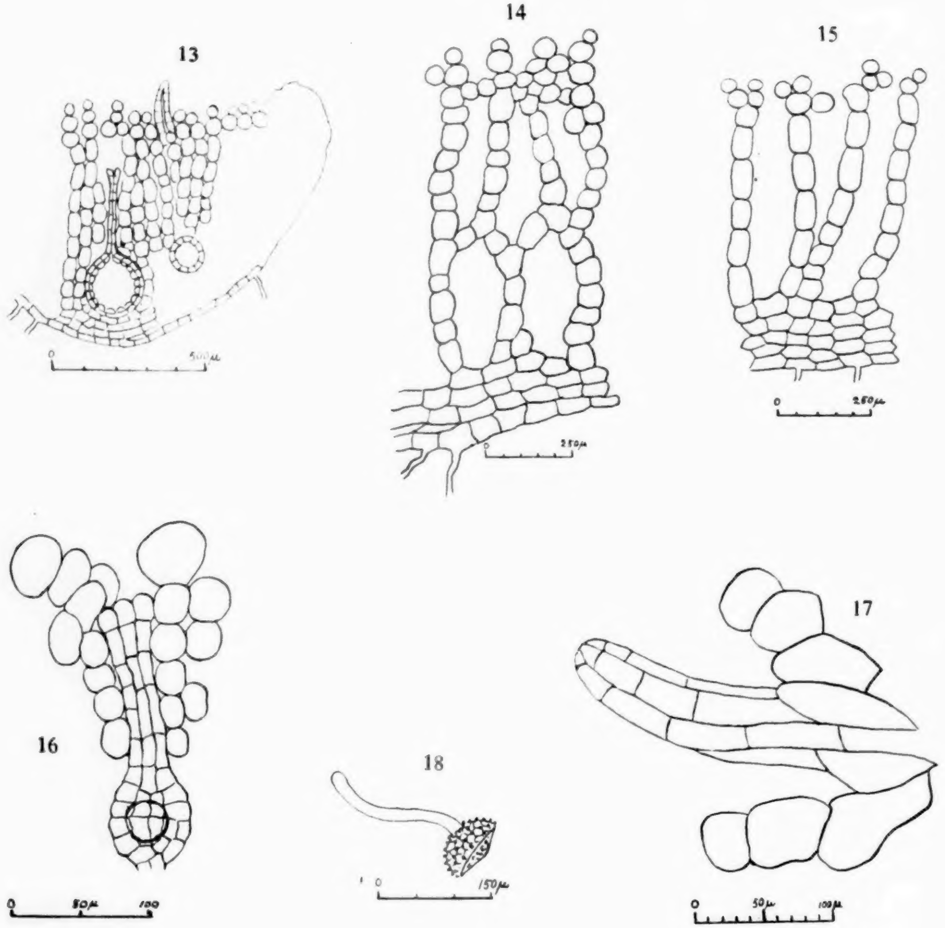
This is one of the commonest of the Stellenbosch *Riccias*. Thalli occur near river banks, along footpaths and sidewalks of the town, and on and near cultivated ground. In favourable seasons where the growths are very dense over a hundred small and crowded thalli have been counted

to the square inch (fig. 8). The greyish-green colour of the plant is characteristic, as is also the markedly crystalline and glistening appearance. In the hundreds of specimens that have been examined from the Stellenbosch district and from widely separated localities throughout South Africa no trace of purple coloration has been observed. Immediately behind the growing point the air-chambers are slit-like and bounded by four columns of chlorophyll-containing cells as in the sub-genus *Euriccia*; but further back they enlarge, though their limits are usually invisible from above, except in the oldest parts of the thallus, where the dorsal surface often becomes pitted as the result of the enlargement of the air-chambers and consequent rupture and contraction of the epidermal cells bordering the pore. The compact layer below the aeriferous zone is four cells or more deep and pale green throughout. Ventral scales sometimes appear to be entirely absent, but a few minute, transitory scales can generally be recognised on the under surface just behind the growing point (fig. 9). Both tuberculate and smooth-walled rhizoids occur.

Antheridia and archegonia are produced in considerable numbers, and are not confined to the middle line of the thallus. In young material they can generally be seen together in a single transverse section (fig. 13). The antheridia are spherical or oblong in form, and never reach the size of those of the two dioecious species. The largest noted were about 150 μ in trans. diam. at the time of sperm discharge, and the wall-cells had enlarged to 28 μ by 40 μ. The colourless and transparent ostioles lengthen to about 200 μ (fig. 17). At the time of fertilisation the archegonial neck is about 160 μ in length (fig. 16), but after fertilisation it may lengthen to about 260 μ, the upper third remaining colourless and collapsing while the remainder becomes rigid and golden-brown in colour.

The ripe sporangia, which are very abundant in the larger thalli, are as a rule hardly visible from above except in water-logged plants, though very conspicuous from below (fig. 10). This is due to the relative thickness of the dorsal zone of aerenchyma and also to the fact that the enlargement of each sporangium causes the zone of compact tissue below it to become slightly convex. Mature sporangia vary from about 0·6 to 0·8 mm. in diam. in well-grown thalli, but stunted thalli 1 mm. long and 0·5 mm. broad may mature a single sporangium of only 0·25 mm. diam.

Young thalli may usually be recognised some little time after the beginning of the rainy season, and where garden soil has been kept watered they have been found in large numbers before the end of April. Mature sporangia are as a rule produced from July to September, though thalli growing in moist clay on the side of an artificial pond immediately above water-level were found to contain a number of ripe sporangia as early as 28th April. By the end of September or the beginning of October most of



R. plana, figs. 13–18.

FIG. 13.—Transverse section of young lobe, with sex organs.

FIG. 14.—Part of transverse section cut across middle line.

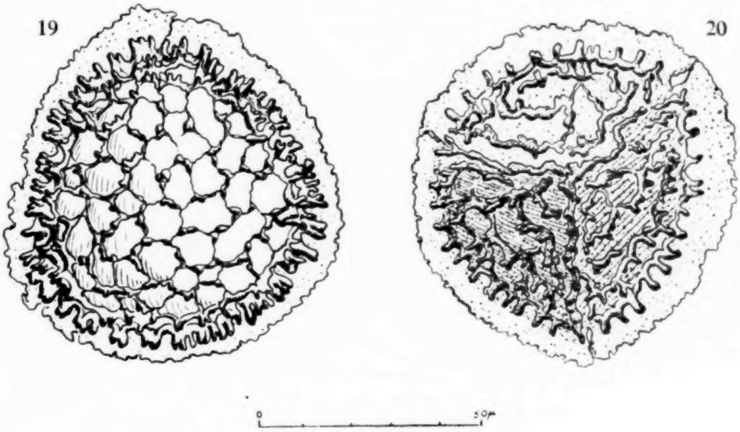
FIG. 15.—Part of transverse section cut parallel to middle line.

FIG. 16.—Archegonium at the time of fertilisation.

FIG. 17.—Old ostiole. FIG. 18.—Germinating spore.

the thalli have disappeared from the more exposed situations, but a few may persist until later in the year in moist, shady spots. Small thalli have been kept fresh and green in the laboratory until the middle of November.

Most of the Stellenbosch plants examined were found to possess spores with incomplete reticulations on the inner faces, but variations in spore size, colour, degree of completeness of reticulum, and extent of wing erosion have sometimes been noted in sporangia of different gatherings or even in those of a single thallus. That these variations may possibly be correlated with differences in environmental conditions during ripening is



R. plana, figs. 19, 20.

FIG. 19.—Spore, outer face.

FIG. 20.—Spore, the three inner faces.

suggested by the fact that the spores of Duthie 5052 show for the most part complete reticulations on all faces.

The spores are set free from the upper surface of the thallus, frequently as the result of the gradual decay of the tissues as a whole. Mature thalli kept continually moist were found at the end of two months to have disappeared almost completely, leaving exposed heaps of spores, a few of which had already begun to germinate from the convex outer face (fig. 18).

In 1932, during an unusually wet summer, enormous numbers of thalli of this species were found carpeting the garden paths and flower beds in the town of Knysna. The smallest plants noted were 2 mm. across, while several unusually large rosettes reached a diam. of 3 cm. The older parts of these large thalli were conspicuously spongy, but the younger parts, as well as the entire tissue of smaller plants, was compact and crystalline.

The whitish appearance of many of the older thalli was the result of attacks of insect larvae, which had hollowed out the middle tissue, often leaving the upper layer entire. The number of spores matured in a sporangium of average size was about 500, but double this number was found in the largest sporangia. As over one hundred sporangia may be produced in a thallus of large size the spore output of a single well-grown plant is considerable. Large numbers of thalli of this species have been collected by Miss E. L. Stephens at Elgin, where in favourable seasons the plants appear to be as abundant as they are in Knysna and Stellenbosch.

Specimens of *Riccia* collected by C. A. Smith at Fauresmith, O.F.S., during 1925 (Cryptogamic Herbarium, Pretoria, 68 and 1069) have an exceptionally spongy thallus. We have not had the opportunity of seeing the Fauresmith plant in the living condition, but there seems little doubt that it is specifically identical with Duthie 5006, as the spores are exactly the same except for the fact that the erosion of the wing frequently shows greater variation.

Riccia cupulifera, A. V. Duthie (sp. nov.).

Figures.—Figs. 21–38 and Plate VII, fig. 2. Also Sim, Trans. Roy. Soc. S.A., xv, p. 14, as *R. crystallina*, fig. A.

Exsic.—Duthie 5097. Stellenbosch, on and near cultivated ground. Aug.-Sept. 1930–1932. Duthie 5321. Platklip, Stellenbosch, on and near granite outcrop. Sept. 1930. Duthie 5322. Kleinberg, Tulbagh. Sept. 1930. Duthie 5323. Kleinberg, Tulbagh, sides of irrigation furrows. Oct. 1935. Duthie 5010. Belvidere, Knysna. Aug. 1929. Duthie 5310. Belvidere, Knysna, cultivated ground. Aug. 1935.

Annua, dioica; frons feminea semiorbicularis vel orbicularis, utplurimum 2–2·5 cm. lata, cavernosa, bis lobatodivisa, lobis obcuneatis, apice retusis; epidermis superior areolata, stomatifera stomatibus simplicibus; nullae squamae ventrales; capsulae sphaericae seriatim immersae, tandem textu contracto in puteis semirotundatis expositae, saepe putei partim conjuncti sunt; sporae maturitate disjunctae, fuscae, 70–110 μ, humiliter subreticulatim-lamellatae, lamellis creberrime papillatis, papillis crassis, apice truncato-rotundatis, ala angusta, 2–8 μ, margine integra; frons masculina e viridi pallens, plerumque semel bis bifurcata; ostiolis antheridiorum conicis, hyalinis.

Dioecious.—*Female thalli* in isolated or crowded complete or incomplete rosettes up to 2·5 cm. in diam., usually bright green,* concolorous beneath. Larger thalli two to three times dichotomously branched, segments oblong or cuneate, divergent or crowded and sometimes overlapping, the apex of segments rounded, truncate or emarginate. Dorsal surface showing poygonal areas, air-pores simple, fairly conspicuous when examined with hand lens, older parts of thallus becoming pitted and cavernous as result of enlargement of air-pores. Cross-section, taken across middle of terminal segment, about twice as broad as high; the dorsal surface flat or slightly channelled, the ventral surface convex, the sides gradually ascending to the obtuse margins. Air-chambers in a single layer. Ventral scales absent. Tuberculate and smooth rhizoids present. *Archegonial* neck 130 to 230 μ in length. *Sporangia* confined to the median line, when mature exposed

* Colour, taken with R. Ridgway's "Color Standards and Color Nomenclature," Cosse Green, Lettuce Green, or Biscay Green.

in hemispherical depressions in the still living thallus tissue; sporangial depressions remaining separate or becoming more or less confluent along median line.

Spores separating at maturity, very angular, medium to dark brown, 70 to 110 μ in diameter. Outer face closely covered with a fine reticulum of undulate walls, which at the nodes are extended into loop-like processes about 2 μ long, with rounded apices. Margin forming a narrow wing 2 to 8 μ wide, its outer edge bordered with a finely granular thickening, marginal angles occasionally with an oval perforation or incised. Inner faces with a reticulum and processes similar to the outer face, but often less complete. Triradiate marking prominent, dark coloured, each radius being an open or almost closed groove bounded on each side by undulate walls, the three grooves confluent at the apex.

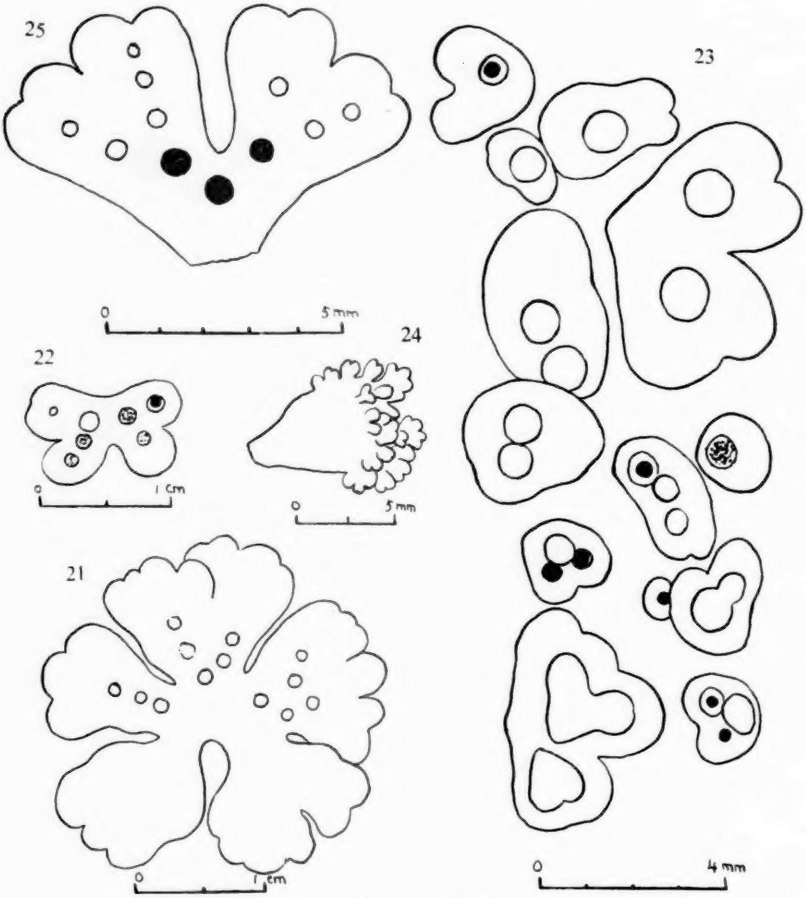
Male thalli light green or yellow-green in colour, without any trace of purple, simple or forked one to three times at a narrow or wide angle, sometimes forming a complete rosette up to 8 mm. in diam. Dorsal surface flat or somewhat concave, ventral surface convex, the margins of larger thallus lobes with well developed air-chambers and air-pores. *Antheridia* crowded; ostioles colourless, transparent, lengthening to over 200 μ.

The above description is based on Duthie 5007.

This species is at present known to occur in the Cape Peninsula and in the divisions of Stellenbosch, Tulbagh, Caledon, and Knysna. In October 1930 it was collected by Mrs. M. R. Levyns in the Cedarberg Mountains, on a peaty slope near a stream, at an altitude of 4000 feet, and it will doubtless prove to be widely distributed in South Africa. It is frequently found growing associated with *R. plana* and *R. Curtisii*, and has in the past been confused with the above species. Fig. A. in the illustration of *R. crystallina* given by Sim in the "Bryophyta of South Africa" was undoubtedly sketched from a specimen of *R. cupulifera*. In the Stellenbosch division it frequents roadsides, garden paths, cultivated land, and shaded river banks, and has been collected at an altitude of 2000 feet as well as on the Stellenbosch Flats at 360 feet. In 1932 enormous numbers of thalli were found on fallow ground on the Municipal Farm, Stellenbosch, where large areas of soil were covered with a pure growth of this species. It has also been found in abundance on coarse, granitic sand at Platklip near the town of Stellenbosch, both on the granite itself and among grass bordering the outcrop.

Thalli usually begin to appear early in June and continue throughout the winter and into early summer. In the Stellenbosch district they may still be found in moist and sheltered spots after the middle of October, long after they have disappeared from more exposed situations. That some of these late thalli originate from spores which have germinated after the main crop is indicated by the presence of small plants bearing sex organs among adult, sporing individuals. Fresh spores taken from thalli in October and placed on damp earthenware began to germinate in less than three weeks, the germ tube being produced from the convex outer face (figs. 35–36).

As in *R. plana* and *R. Curtisii* the thalli vary greatly in size and



R. cupulifera, figs. 21–25.

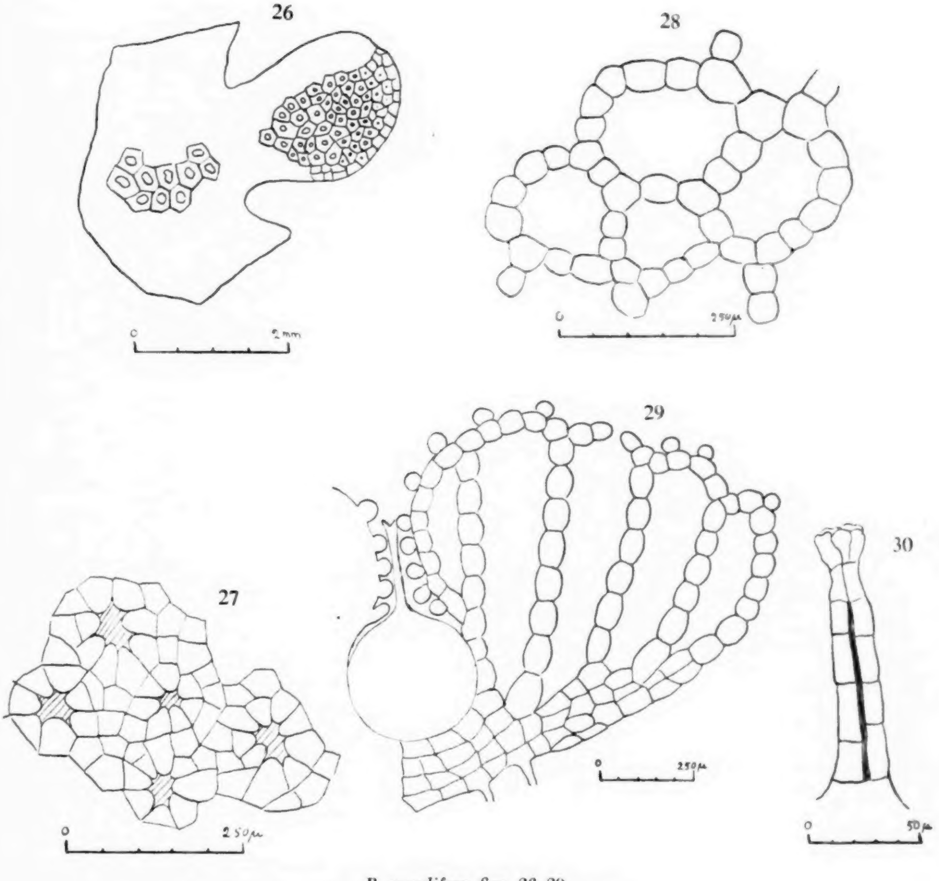
Fig. 21.—Large rosette-shaped female thallus.

Fig. 22.—Small butterfly-shaped female thallus.

Fig. 23.—Stunted female thalli, showing sporangia and sporogonial cavities.

Fig. 24.—Branch of abnormal female thallus with much-lobed margin.

Fig. 25.—Part of female thallus showing distribution of sporangia.



***R. cupulifera*, figs. 26–29.**

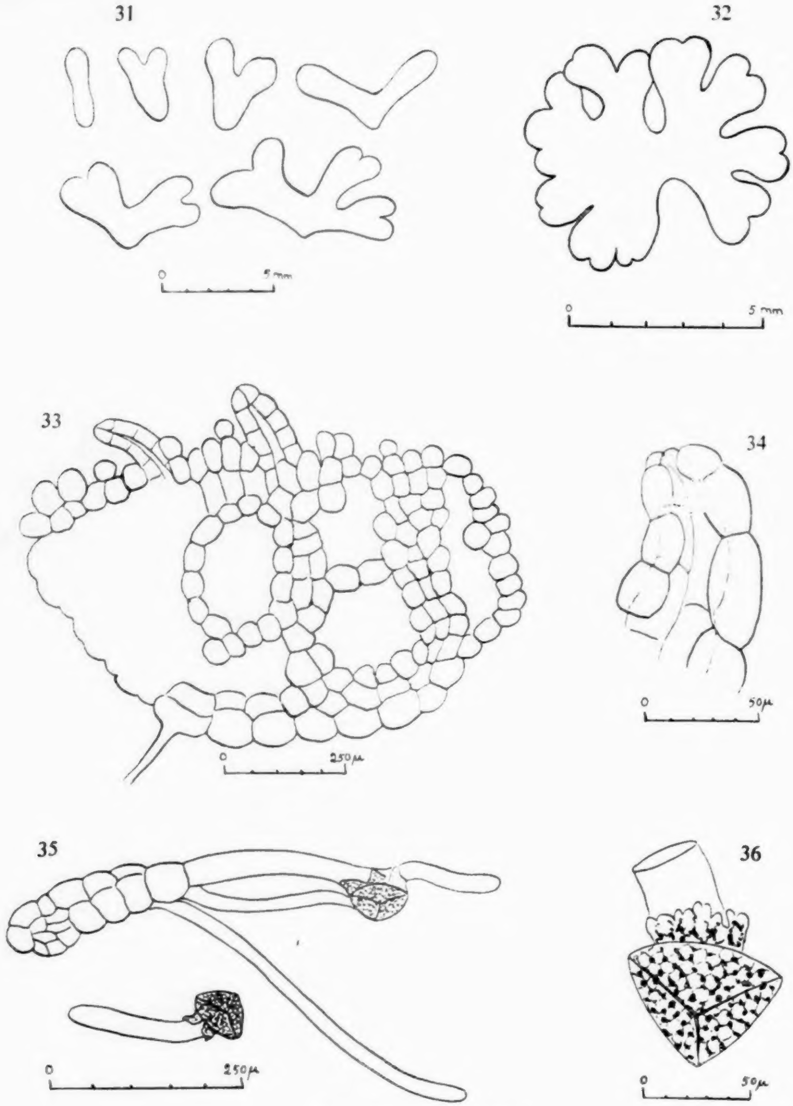
FIG. 26.—Dorsal surface of female thallus with areolae and air-pores.

FIG. 27.—Dorsal surface of young lobe of thallus showing air-pores (scattered convex cells not shown).

FIG. 28.—Horizontal section through photosynthetic zone of female thallus.

FIG. 29.—Transverse section through female thallus, with old archegonium.

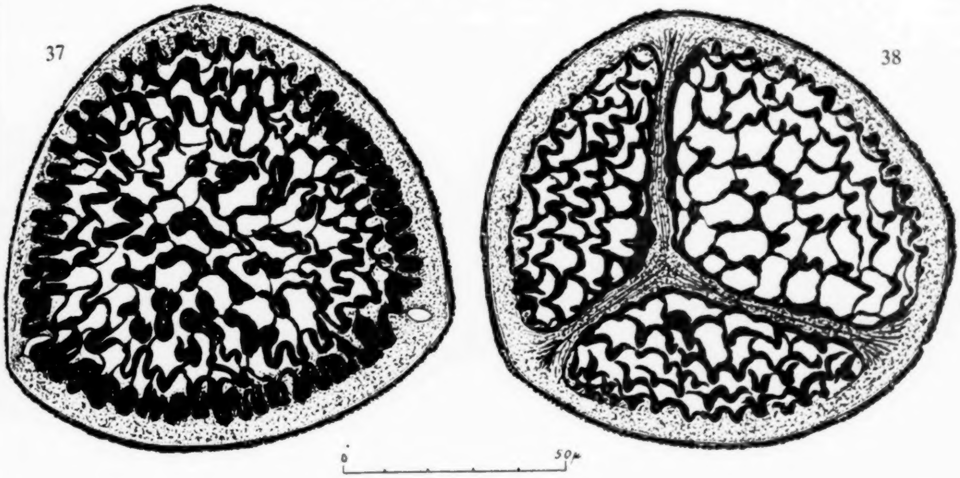
FIG. 30.—Neck of old archegonium.



R. cupulifera, figs. 31–36.
FIG. 31.—Male thalli.
FIG. 32.—Large male thallus from Plattklip, Stellenbosch.
FIG. 33.—Transverse section through male thallus.
FIG. 34.—Antheridial ostiole.
FIGS. 35, 36.—Germinating spores.

shape (figs. 21–23 and Pl. VII, fig. 2). Where densely crowded undersized thalli are of frequent occurrence (fig. 23) these are sparingly lobed or simple, and it is not unusual to find adult female thalli 1 mm. long which have matured one or two sporangia. Distorted forms of both male and female thalli may result from injury to the growing points, or from rapid lobing of old thalli which have been kept moist and grown in reduced illumination (fig. 24). In colour the female thalli of *R. cupulifera* often

37 38



R. cupulifera, figs. 37, 38.
FIG. 37.—Spore, outer face.
FIG. 38.—Spore, three inner faces.

resemble those of *R. Curtisii* rather closely, though they generally lack the definite yellowish tinge which is so characteristic of the latter species. When strongly illuminated the thalli of *R. cupulifera* are often lighter green and somewhat bleached looking, but they never become purple.

If the female thallus is examined with a hand lens the limits of the uniseriate air-chambers are visible from above. The roof of each air-chamber is often slightly convex, and is perforated by a centrally placed air-pore, which enlarges by rupture and contraction of the marginal cells as the air-chamber increases in size (fig. 26). In texture the older parts become rather loose and spongy, though not as conspicuously so as in *R. Curtisii*. A marked feature of the young thallus is the presence on the dorsal surface of scattered convex or papillate cells, which may reach a length of 40 μ. These are especially numerous in the neighbourhood of the archegonial neck and near the growing apex of the thallus, but they

never occur in the same abundance as in *R. plana* (fig. 29). A dimple-like depression in the dorsal surface usually marks the position of the archegonium or immature sporogonium (figs. 21, 29). After fertilisation the lower part of the archegonial neck becomes dark brown, while the cells nearer the apex remain colourless and collapse (fig. 30). The compact cells below the zone of air-chambers are from 3 to 5 layers deep and contain scattered chloroplasts.

The male thalli are usually smaller in size and lighter in colour than the female, though rosettes of from 5 to 8 mm. in diameter are occasionally seen (figs. 31, 32). The antheridia are very numerous. At the time of sperm discharge the ostioles do not project very markedly from among the papillate cells of the dorsal surface, but later they elongate to over 200 μ and are often visible in profile to the naked eye (figs. 33, 34).

A striking feature of the species is the splitting and contraction of the living thallus tissue from about the ripening sporangium, which causes the brown sporangium, surmounted by the old archegonial neck, to be exposed in a smooth-walled, bowl-shaped depression. Later the venter of the archegonium disintegrates, leaving a heap of loose spores at the bottom of the depression. In old thalli these depressions are usually more or less confluent along the middle line, forming gutter-like channels in the green tissue, from which the spores are readily washed by rain water (fig. 23 and Pl. VII, fig. 2), but when the sporangia are less crowded a series of empty, cup-like hollows is often seen. The sporangia may reach a diameter of 0·7 mm. in well-grown thalli. When crowded they are often laterally compressed.

In the absence of mature spores the female thallus of *R. cupulifera* may be distinguished from that of *R. Curtisii* by the following characters:—

1. The more compact texture of the thallus, and the presence of well-marked areolae on the dorsal surface. 2. Abundant tuberculate rhizoids. 3. Brown coloration of lower part of neck of old archegonium. The male thallus can be distinguished from that of *R. Curtisii* as follows: 1. Complete absence of purple coloration. 2. Dorsal surface as a rule not markedly convex. 3. Abundant tuberculate rhizoids.

Riccia Curtisii (Austin) T. P. James.

Riccia Curtisii (Austin) T. P. James, Proc. Acad. Nat. Sci. Phil, p. 231. 1869.

Cryptocarpus gen. nov. Austin, Ms., 1864.
Thallocarpus gen. nov. S. O. Lindberg, in Not. F. et Fl. Fennica, 13, 377, 1874.
Thallocarpus Curtisii, Austin, Bull. Torr. Bot. Club, 6 : 21, 1875.
Angiocarpus Curtisii Trevisan, Mem. Ist. Lomb., 13 : 444, 1877.
Riccia crystallina L. (pro part), Sim, Trans. Roy. Soc. S.A., xv, p. 13.

Type.—On moist ground, South Carolina, Ravenel. (in Herb. Sulliv.), 1849, and Society Hill, Carolina. Leg. Dr. M. A. Curtis, 1853.

Figures.—Figs. 39–54 and Pl. VII, fig. 1. Also Bull. Torr. Bot. Club, 47, pl. 13, fig. 9 (spore).

Sim, Trans. Roy. Soc. S.A., xv, 14. Fig. *R. crystallina* D.

Exsic.—Duthie 5008. Stellenbosch, on and near cultivated ground. Sept. 1933–1934. Duthie 5320. Rosebank, garden paths and flower beds. Sept. 1929–1930. Duthie. Kleinberg, Tulbagh, along sides of irrigation furrows. Oct. 1935.

Dioecious.—*Female thalli* in isolated or crowded complete or incomplete rosettes up to 2 cm. diam., pale or dark yellowish-green in colour,* concolorous beneath, the larger several times dichotomously branched. Thallus lobes varying much in form and diameter according to age and extent of crowding, the apex of segments rounded or emarginate. Dorsal tissue, except in immediate neighbourhood of growing point, very loose and spongy. Air-chambers uniseriate, enlarging greatly in older parts of thallus. Air-pores small and inconspicuous behind growing apex, but rapidly enlarging with the enlarging air-chambers by separation and contraction of the unmodified epidermal cells bordering the pore. Ventral scales not seen. Tuberculate rhizoids usually absent, but smooth-walled rhizoids abundantly produced. *Archegonial* neck 200 μ or less in length, the lower part becoming deep purple after fertilisation, the purple coloration sometimes extending to the neighbouring thallus cells. Capsule wall disintegrating before the tetrad division of the spore mother-cells. *Sporangia* 0·5 mm. to 0·7 mm. in diam. Spores light or somewhat dark brown in colour, permanently adhering in tetrads, which are 80 to 112 μ in diam. Convex face with straight, stout, truncate spines, about 3 μ long in the centre of the face, becoming shorter towards the periphery. Bases of the spines united into a distinct reticulum. *Male thalli* usually much smaller than the female, and often more or less overgrown by them, simple or once or twice forked; when old often dark purple in colour, or the purple coloration confined to the crest of each lobe. Dorsal surface usually strongly convex, with convex papillate cells and very numerous and conspicuous ostioles; ostioles colourless and transparent, lengthening to 200 μ.

This description is based on Duthie 5008.

Thalli of the Stellenbosch plant have been compared with published descriptions and drawings of *R. Curtisii* and also with the type material (leg. Dr. Curtis, 1853), and there seems to be no doubt that the South African species is identical with that collected by Curtis in Carolina. Thalli have also been compared with preserved material from Austin, Texas, kindly supplied by Dr. F. McAllister. The male thalli of McAllister's material were found to agree closely with those of the Stellenbosch *R. Curtisii* except for the fact that the dorsal surface was less convex and that some of the oldest ostioles were more conspicuously elongated. The spongy female thalli too were very like those from Stellenbosch, as were also some of the spore tetrads examined. McAllister's (34) published photographs of living male and female thalli of *R. Curtisii* from Austin, Texas, as well as his reference to the reddish-brown colour of the central region of old male thalli, agree exactly with the Stellenbosch plant.

* Colour, taken with R. Ridgway's "Color Standards and Color Nomenclature," Cosse Green, Oil Green, and in old thalli often yellowing to Oil Yellow.

A study of the published descriptions of American plants indicates that there are two varieties of *R. Curtisii* in that country.

Caroline Hayes (19) clearly describes and figures two spore types as follows: "Fig. 9 (pl. xiii). Spore tetrad, showing very blunt papillae and very low connecting basilar ridges . . . from specimens collected by Mary Young, Austin, Texas, March 3, 1914," and "Fig. 10. Spore covered with more conical papillae . . . from a specimen collected by Severin Rapp, Sanford, Florida. April 12, 1911."

Howe (22) repeats this distinction of two types of spore, which he described as having "obtuse truncate verruculae, 2–3 μ high," and "obtuse, truncate, or subacute spinules 3–6 μ high, these seated at the angles of an obviously or scarcely visible reticulum."

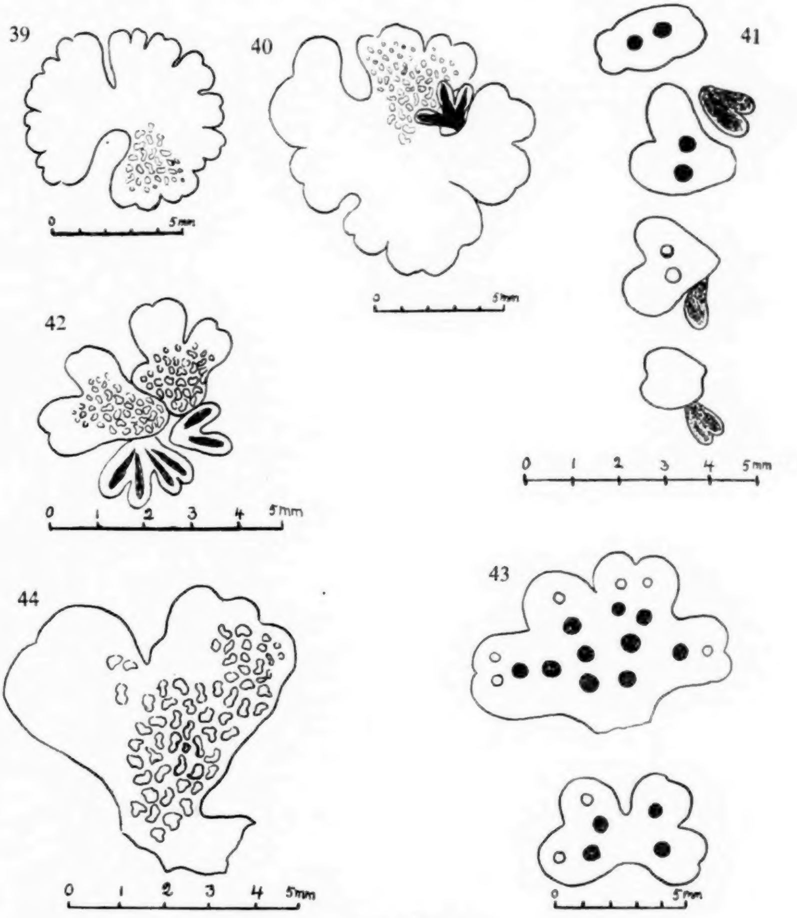
We have examined type material collected by Dr. Curtis, and find that it agrees exactly with Duthie 5008 in having blunt spines from the nodes of a delicate reticulum which is very clearly visible in the centre of the outer face. The thallus characters of our plant also agree closely. The thallus form in American material appears to be correlated with the spore characters. We have examined Verdoorn. Hep. Select. et Crit., vii, 1934, No. 347, Florida, Sanford, distributed under the name *R. Curtisii*, and find that it has a spore tetrad which averages 100 μ diameter, the outer faces without reticulum, and provided with verrucae or conical, sometimes truncate spines (fig. 53). This spore type is correlated with a loosely branching thallus, some of the branches of which are 2 cm. in length. The plant from Florida obviously requires a re-examination from fresh material, as it is possibly a distinct variety. Such a form has not yet been found in South Africa.

Although no spores which lack a reticulum entirely have been recorded from South Africa, the extent of development of the reticulum has been observed to vary in different gatherings, being in some very distinct, in others less evident. The length and form of the spines also exhibits some variation.

The spores of a tetrad may occasionally have a marked inequality of size, and abnormal tetrads have been observed in which the spores have a rhomboidal arrangement, with the four spores in one plane.

The plant now known as *Riccia Curtisii* was formerly placed in the Sphaerocarpales on account of the adherent spore tetrads and the supposed absence of reticulate rhizoids; but McAllister (34) in 1916 emphasised its close alliance with *Riccia*, and Howe (22) includes it in that genus.

A detailed examination of large numbers of South African plants has revealed the presence of occasional tuberculate rhizoids in both male and female thalli, also noted by Howe (*loc. cit.*), and this discovery removes the only valid reason for the use of a distinct generic name. The tubercles



R. Curtisii, figs. 39–44.

Fig. 39.—Female thallus.

Fig. 40.—Male and female thalli.

Fig. 41.—Stunted male and female thalli.

Fig. 42.—Group of two male and two female thalli.

Fig. 43.—Under side of female thallus showing distribution of sporangia.

Fig. 44.—Dorsal surface of female thallus.

in the rhizoid may be few and scattered, or abundant and crowded, and they vary in length from 1 to 8 μ.

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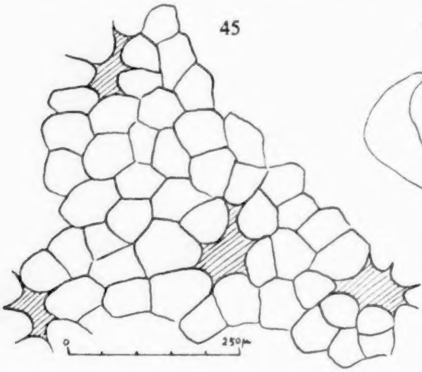

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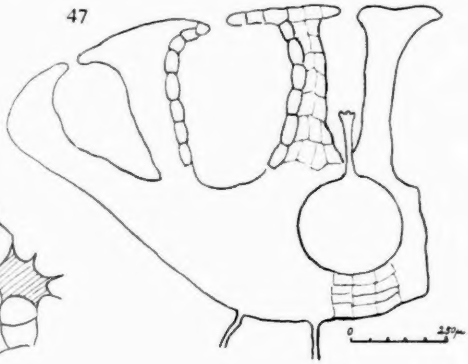

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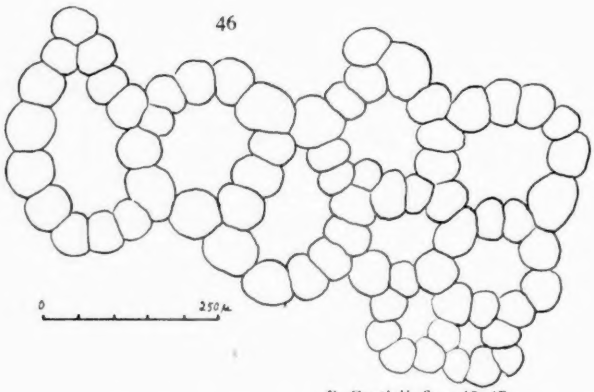

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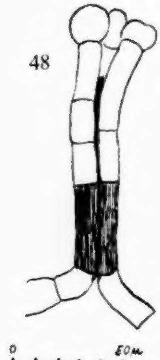
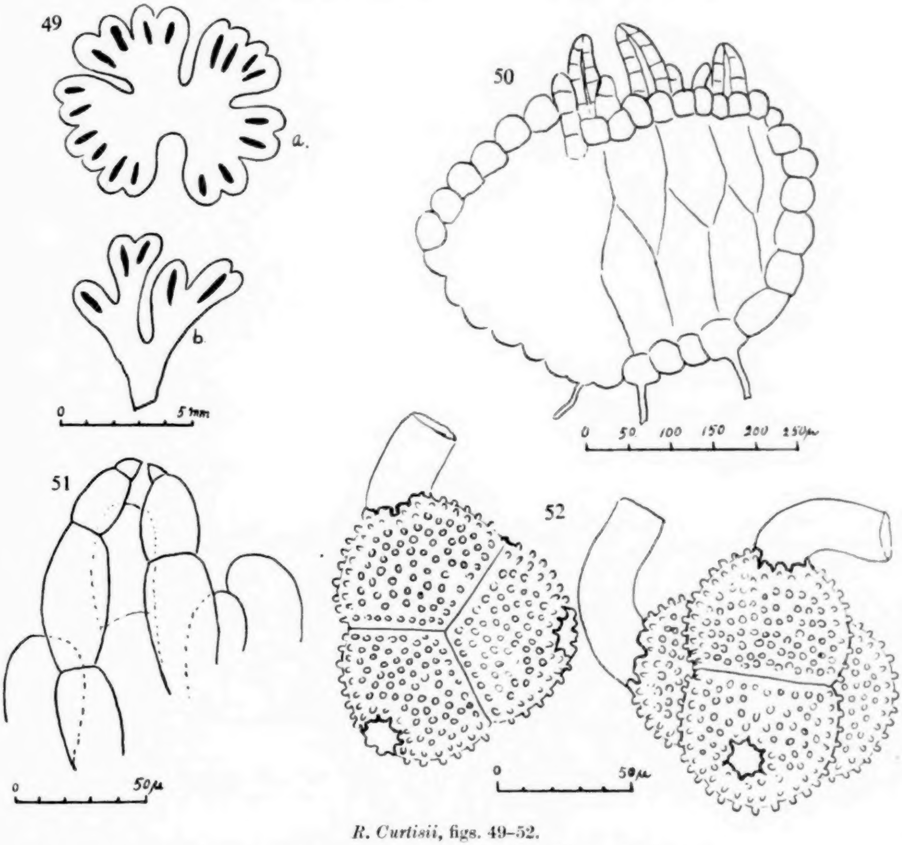


R. Curtisii, figs. 45–47.

FIG. 45.—Dorsal surface of young lobe of female thallus showing air-pores.
FIG. 46.—Horizontal section through photosynthetic zone of female thallus.
FIG. 47.—Transverse section through female thallus, with old archegonium.
FIG. 48.—Neck of old archegonium.

This species is common in the Stellenbosch and Cape divisions, where it occurs in the same habitat as *R. plana* and *R. cupulifera*, either intermixed

with one or both or growing alone. It appears to be widely distributed in South Africa, and has been collected in various localities in the Cape Peninsula and in the divisions of Stellenbosch, Tulbagh, Caledon, and



R. Curtisii, figs. 49–52.

FIG. 49.—*a* and *b*, male thalli (*a* from the Knysna District).
FIG. 50.—Transverse section through male thallus.
FIG. 51.—Antheridial ostiole.
FIG. 52.—Germinating spore tetrads.

Knysna. Thalli collected by Miss L. Britten in August 1929 on the outskirts of native bush between Port Alfrid and Hayes Siding apparently belong to the above species, as do a few plants collected by Miss E. L. Stephens on damp soil, south edge of Chobe Swamp, British Bechuanaland.

The possibility of the spores of *R. Curtisii* having been introduced into South Africa with garden soil or seeds has been considered, but as thalli often occur far removed from cultivated areas it would seem safe to conclude that the species is in all probability a native.

In the Stellenbosch district young thalli can usually be recognised before the end of May, either scattered or occasionally massed in groups which have resulted from the germination *in situ* of the spores of one or more sporangia. Over 80 thalli, varying in size from a few cells to plants 1 mm. across, with well-developed air-chambers, have been found in a single group. Such crowded thalli are usually of small size when mature, both male and female plants being simple or very sparingly lobed (fig. 41). In exposed situations thalli have usually disappeared before the end of September, but plants may still be found in moist, shaded spots until near the end of October. Some of these thalli bear sex organs, and have apparently originated from spore tetrads which have germinated late in the season.

The female thalli are usually bright yellow-green in colour, and except for the extreme tips of the lobes very loose and spongy in texture. Chlorophyll extends as a rule to the under surface, which is devoid of ventral scales. Occasionally, especially rather late in the season, pale green or yellowish specimens may be found which resemble in colour male thalli which have grown in deep shade. These paler female thalli are usually more compact in texture and lack the gaping air-chambers of the usual form, but the spore characters are typical of *R. Curtisii.*

Well grown isolated rosettes are usually from 1 to 1·5 cm. across, and may occasionally reach a diameter of 2 cm. and a thickness of 1·5 mm. (figs. 39, 40).

The number of sporangia produced by well-grown plants is usually large, and their distribution can be readily seen from below if the under surface is freed from soil (fig. 43). They vary in diameter from 0·5 to 0·7 mm. in a single thallus, and may be dissected with ease from the somewhat brittle tissue in which they are embedded. The spore tetrads are usually set free by the decay of the upper spongy tissue. Each spore of the tetrad germinates from the middle of the convex face (fig. 52).

The colour of old male thalli which have been exposed to strong illumination is usually dark purple or red-brown, and so much the colour of the soil that the plants may escape detection. The purple colour extends to the ventral surface, but the extreme apex and the margins of the thallus are often pale green. Strongly convex, papillate cells, the walls of which are unpigmented, are present in large numbers on the dorsal surface. The ostioles (figs. 50–51), which are formed in abundance, are colourless and transparent, and may elongate after sperm discharge to 200 μ or more.

The wall-cells of the antheridium become greatly enlarged and distended before the liberation of the sperms. A transverse section through a lobe less than 0·5 mm. wide may show two or more antheridia. The dorsal surface of the male thallus is usually strongly convex (fig. 50). The intensity of the purple coloration appears to vary with the age of the thallus and the intensity of the illumination to which it has been exposed during growth. In shade thalli the purple tint is often confined to the

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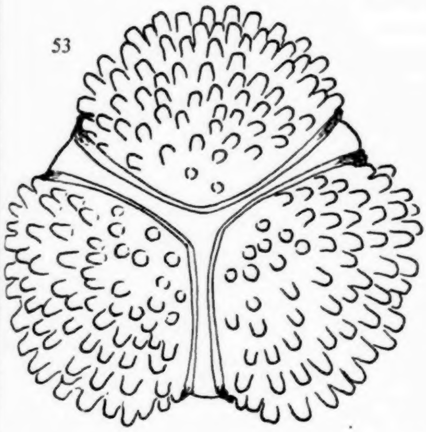

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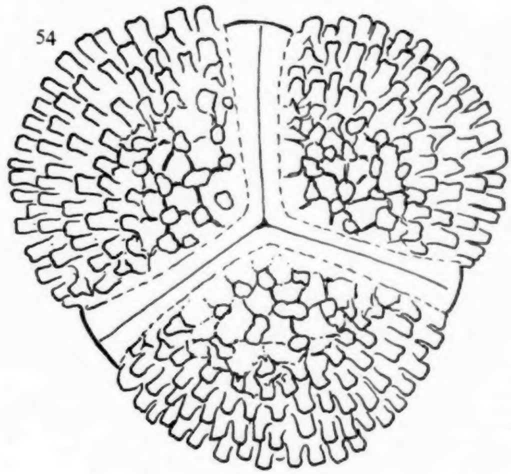

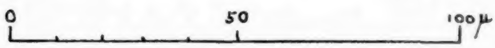

FIG. 53.—Spore tetrad of *R. Curtisii* (Verdoorn, vii, 347, 1934).
FIG. 54.—Spore tetrad of *R. Curtisii* (Duthie 5008).

crest of a lobe, or it may be almost entirely absent, when the colour of the thallus often approximates to that of the female plant. The smallest male thalli noted were unlobed and less than 2 mm. long and 0·5 mm. wide, but the majority are once or twice forked. Large male plants, approaching more nearly the size of well-grown female thalli and resembling them in colour and texture, are occasionally met with, especially in shaded situations. Unusually large male thalli were found at Belvidere in the Knysna district during the winter of 1930, where this species occurred in enormous numbers, growing among grass and on the surface of old mole hills along the outer edge of an oak avenue. The largest noted was an almost complete rosette 8 mm. across (fig. 49, *a*).

In his published work dealing with *R. Curtisii* in Texas, McAllister

(35) has drawn attention to the frequent grouping in the field of two male and two female thalli, indicating that sex segregation takes place at the time of the reduction division, though he was unable to detect any definite and constant difference between the chromosomes of the two sexes. Siler (47), on the other hand, reports the presence of 7 large and 1 very small chromosome in male thalli of *R. Curtisii* from Georgia, and of 7 large and 1 somewhat shorter chromosome in female thalli from Florida; while Lorbeer (33), who investigated material from Sanford, Florida, describes a small X chromosome in the male and a large Y chromosome in the female, which pair in the sporophyte. These contradictory results suggest again the presence of two distinct varieties or strains of *R. Curtisii* in America, possibly correlated with the difference in spore marking already referred to. A grouping of male and female thalli similar to that described by McAllister is very often seen in South African material (fig. 42). At the end of 1929 an attempt was made to obtain, experimentally, definite data that the spore tetrads mature equal numbers of male and female thalli. The soil in several large pots was sterilised, the surface divided into squares, and a single spore tetrad was transferred to the middle of each square. Over a hundred tetrads were isolated in this way. The pots were then covered with glass, and some were sunk in the soil outside, while others were kept in the greenhouse and watered from below. Unfortunately

No. of thalli developed from spore tetrad.	Male.	Female.	Doubtful.
4 (stunted and overgrown by Funaria)	1	..	3
3	2	..	1 (apparently female)
3	..	..	3
2	1	1	..
2	2	..	..
2	1	..	1 (apparently female)
2	..	..	2
1	..	1	..
1	..	1	..
1	1	..	..

when the pots were examined at the end of the long vacation it was found that attacks of insects and growth of moss had interfered seriously with the experiment. The results, though inconclusive, are possibly worth recording (see Table on p. 130). The sex of the thalli was determined microscopically by the presence of archegonia and ostioles.

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EXPLANATION OF PLATE.

1. *R. Curtisii* T. P. James. Group of male and female thalli.
2. *R. cupulifera* sp. nov. Female thalli to right and left, showing manner of freeing the spores. Two male thalli in centre, the upper much-lobed.
3. *R. plana* Taylor. Monoecious thalli.

Photographs by S. Garside, from living plants collected on the Stellenbosch Flats, September 1933.

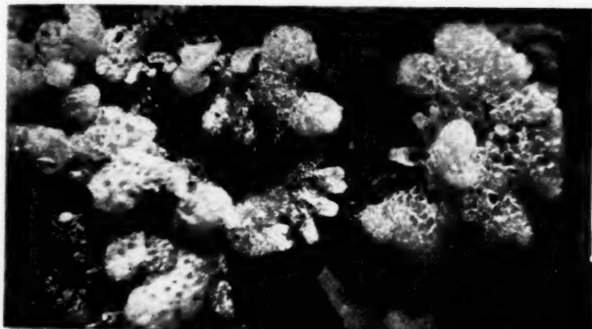


FIG. 1.—*Riccia Curtisii* T. P. James

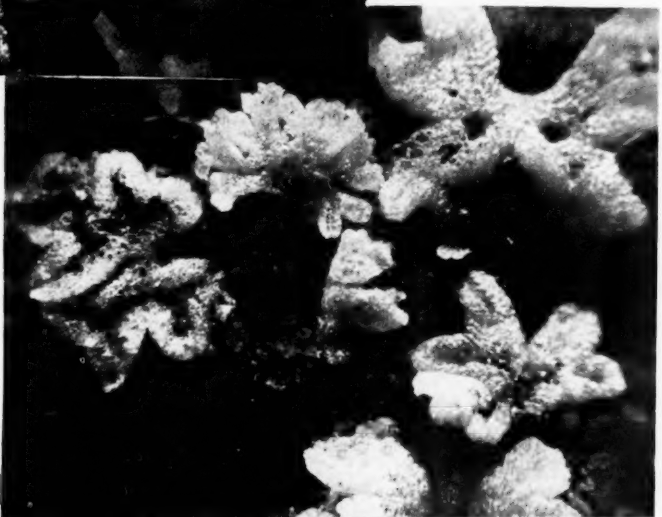


FIG. 2.—*Riccia cupulifera* Duthie.

Millimetres.

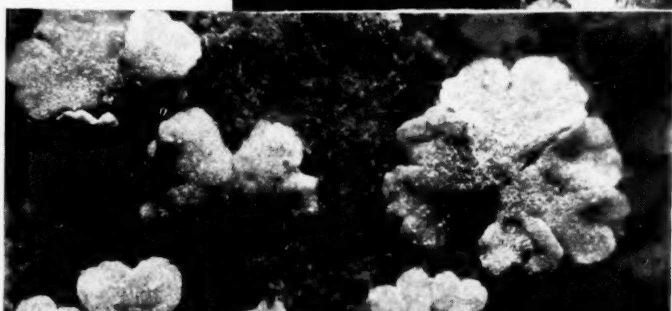


FIG. 3.—*Riccia plana* Taylor.

A. V. Duthie and S. Garside. *Neill & Co., Ltd.*

THE RELATIONSHIP BETWEEN WINTER RAINFALL AND BAROMETRIC PRESSURE, BAROMETRIC TENDENCY AND WIND DIRECTION AT CAPE TOWN.

By Hildegarde E. Morrison, M.Sc., and
Professor J. T. Morrison, D.Sc., F.R.S.E.

(With twenty-three Text-figures.)

(Read March 18, 1936.)

§ 1. The following investigation deals with the relation between the daily barometric pressure at a point in the winter-rainfall area of the Union of South Africa during the winter months and the *amount* of rain falling there during the ensuing twenty-four hours. Its purpose is to discover whether, for various types of winter weather in this area, the relationship which, roughly speaking, must exist between barometric pressure and *amount* of consequent rainfall can be put into the form of some simple mathematical function or functions, and to determine how closely the rainfall calculated from such function or functions fits the observations, regard being had to the variability of the observed rainfall itself.

The investigation was undertaken at the instance of the Chief Meteorologist of the Union, Dr. T. E. W. Schumann, who also placed the necessary data at our disposal and took a constant interest in its progress; and all the numerical and graphical work was done by one of us, as part of her professional work in the Meteorological Office.

§ 2. The south-westerly parts of the Western Province of South Africa are the parts of winter rainfall, the wettest months in these districts being May, June, July, and August. The rainfall is mainly associated with the arrival from a westerly direction of a series of travelling depressions, which probably are a northerly extension of the great belt of eastward-moving depressions, that mark the interlacing of the west and north-west winds of the "roaring forties" with south and south-east winds of higher southern latitudes. The motion of the sun to the north of the equator in the months of the southern winter doubtless carries this belt north with it, and the fringe of the depressions reaches the south-west and southern coasts of South Africa, the inland parts to east and north

being, however, protected from invasion by the anticyclonic conditions arising from their elevation and their lower latitude.

The northern portion of a depression in the Western Province is the rainy part. Its oncoming is generally heralded by north-easterly to northerly winds accompanied by a fall in the barometer. The wind turns to north and north-west with usually steady rains, then to west and south-west with gusty rains, a fall of temperature, and a steady or even rising barometer, clear weather returning with cold southerly winds. The winds of the drier southern portion of the depression naturally range from south-south-west round through south and east to north-east.

§ 3. With these well-known facts in mind, it was thought proper to classify all the days of observation according to two features, belonging entirely to the observing station, namely, (i) the behaviour of the barometer during the three days preceding the day of observation, (ii) whether the wind on the morning of observation lay in the north-north-east, north, west, south-west semicircle, or in the other. Several other factors might have been taken into account in arranging the days in groups of typical weather; but it was necessary for statistical purposes to limit the number of groups, and it was also thought well that a first discussion should be confined to the association of the *amount* of rainfall with barometric pressure and changes of pressure, taken along with the above-mentioned characteristic groups of winds.

§ 4. As wind direction was to be used in the weather classification, it would have been desirable to select a typical station with an open situation well removed from mountains. In the absence of such a station in the area with a sufficiently long and reliable set of observations, choice was made of the station at the Somerset Hospital, Portswood Road, Cape Town, where careful observations had been made during a considerable number of years. In spite of the nearness of this station to Table Mountain and its outliers, Lion's Head and Signal Hill, it was considered well to select it on account of the reliability and continuity of its observations. On the north and north-west, the station faces the open sea; Table Bay lies to the east and north-east, with fairly flat country stretching beyond for nearly thirty miles. Signal Hill and Lion's Head rise almost due south, their lower slope beginning only a few hundred yards away, and Table Mountain fills all the south-east to east horizon. There is thus little deviation of the first or north-westerly group of winds, except of those from the south-west. Some of these blow over the Kloof Nek between the Lion's Head and Table Mountain, and reach the station as a south or even south-south-east wind. In cases where this effect was suspected, a comparison was made with the wind at the better-exposed Cape Point lighthouse.

§ 5. The observations analysed were those made daily at the above-mentioned station during the months of May, June, July, and August of the years 1916 to 1934, inclusive. The observations were made at 08.30 S.A.M.T. The rain-gauge reading was entered up against the previous day, so that opposite each date one found the barometric pressure at 8.30 that morning and the rainfall that followed during the next twenty-four hours. What was sought for was a formula connecting these two readings, the readings being, however, first classified into groups according to the changes of pressure of the three preceding days and the prevailing wind on the morning of the observation.

The changes of pressure were dealt with as follows:—

Any rise of pressure on the third day preceding an observation was called +, any fall −; a rise exceeding 5 hundredths of an inch on the second day was called +, a change lying between +5 and −5 (inclusive) 0, a fall exceeding 5 hundredths −; and the day preceding the observation was dealt with in the same way as the second preceding day. All the observations were then grouped on the basis of these changes into the following 18 groups:—

dp during 3rd day previous to observation.	*dp* during 2nd day previous to observation.	*dp* during day previous to observation.	S.
+	+	+	Group 1
+	+	0	,, 2
+	+	−	,, 3
+	0	+	,, 4
+	0	0	,, 5
+	0	−	,, 6
+	−	+	,, 7
+	−	0	,, 8
+	−	−	,, 9
−	+	+	,, 10
−	+	0	,, 11
−	+	−	,, 12
−	0	+	,, 13
−	0	0	,, 14
−	0	−	,, 15
−	−	+	,, 16
−	−	0	,, 17
−	−	−	,, 18

Each group was now divided into two sections, namely, one of A winds, ranging from north-north-east through north to south-west, and

one of the B winds from south-south-west through south to north-east; and each section was dealt with separately.

§ 6. To facilitate the division into groups, the observations were in the first place set down in the following way:—

May 1916. Date.	P.	*dp*.	S.	R.	W.
1st	124	+	16	0·01	A
2nd	121	0	11	0·40	A
3rd	113	–	6	0·04	A
4th	122	+	16	0	A
5th	122	0	11	0	A
6th	125	0	5	0	B

P = barometric pressure at 08.30 on given date in hundredths of an inch, less 29 inches. Thus 124 = 30·24 inches, 74 = 29·74 inches, etc.

dp = change of pressure during twenty-four hours prior to 08.30 on given date, classified as already described, namely:—

+ = rise of 6 or over;
0 = from fall of 5 to rise of 5 (inclusive);
– = fall of 6 or over.

S is the number of the group to which the day belongs, *e.g.* S for the 3rd May above is group 6, since the change on the three days previous to the observation is + 0 – .

If *dp* is entered as 0 during the 3rd day previous to the observation, then in assigning S the actual sign of the change had to be taken, regardless of the size of the rise or fall. *E.g.* on 4th May the changes entered were 0 – +, but since the change of pressure, *dp*, on 2nd May was actually 121–124, *i.e.* negative, S was taken to be – – +, namely, group 16. If *dp* was actually 0 during the third day prior to the observation, as in the case of the observation of 7th May, then *dp* on the day prior to that was taken.

R = actual rainfall during the 24 hours following the observation. *E.g.* rain on 5th May = amount of rain that fell from 08.30 on 5th May to 08.30 on 6th May. R is given in inches to the nearest hundredth.

W = direction of the prevailing wind at the time of observation.

The data were then sorted into the 18 groups of S—that is, according to the change of pressure during the three days preceding the observation —and each of these 18 groups again divided into two sections, namely, a section with A winds and one with B winds.

We therefore have readings of P, the pressure at 08.30 on the day of

observation, and corresponding values of R, the ensuing rainfall, in each of the 36 groups so obtained.

§ 7. The P values of each group were now rearranged in ascending order of pressure, and the corresponding rainfalls set opposite, as set forth in the table (pp. 140–141), which shows how the data for group 8 (S = + − 0), A winds, were dealt with.

The n observations of the group were divided into sub-groups of 5 each, distinguished by $r=1$, $r=2$, etc. In the case of group 8A, $n=71$; the last sub-group is $r=14$, and it contains 6 instead of 5 observations. The *sub-group means* for P and R were calculated and appear under the letters $\bar{P}_r$ and $\bar{R}_r$. If, as in the case of sub-groups $r=3$ and $r=4$ in the table, observations at the same value of pressure fall into two adjacent sub-groups, the total rainfall at that value of P was divided proportionally between the sub-groups concerned. These new values of R are inserted within brackets next to the actual values of R.

The mean daily rainfall of each sub-group, and also the mean and the standard deviations from that mean, were then calculated, and are set down under the letters:

$\bar{R}_r$ = the mean daily rainfall of the rth sub-group.
d_r = the mean deviation of rainfall within the rth sub-group.
σ_r = the standard deviation of rainfall within the rth sub-group.

Again when observations at the same pressure fell into two sub-groups, the *sum of the squared deviations* of R at this value of pressure from its mean was divided proportionally between the sub-groups concerned in the case of the standard deviation and the *actual deviations* themselves in the case of the mean deviation.

§ 8. The problem now consists in fitting a curve to the $\bar{R}_r$ and $\bar{P}_r$ data of each of the 36 groups in order to determine the most probable amount of mean rainfall at each value of pressure in that group. Although the rainfall was by no means normally distributed within each sub-group, it was thought to be on the whole advisable to judge goodness of fit by the smallness of the sum of the squares of the deviations of the observed $\bar{R}_r$ values from those given by the selected curve. One advantage of this test is, as is well known, that thereby the mean square deviation of the individual rainfalls from the calculated values also becomes a minimum. Therefore it was only necessary to choose a curve which appeared to give the best fit to the sub-group *means* $\bar{R}_r$ plotted against the corresponding $\bar{P}_r$, the curve being chosen to make $\Sigma(\bar{R}_r - \bar{R})^2$ a minimum, where $\bar{R}$ was the calculated value.

Inspection of the tabulated reduced observations and of the plotted values of $\bar{R}_r$ against $\bar{P}_r$ showed great variations of rainfall within many

GROUP 8A.

r.	$\bar{P}_r$.	P.	R.	$\bar{R}_r$.	d_r.	σ_r.
1	92·2	79 92 96 97 97	0·84 0·15 0·32 0·85 0	0·432	0·330	0·352
2	101·6	98 101 102 102 105	0 0·42 0·30 0·44 0	0·232	·186	·195
3	106·6	106 106 106 107 108	0·04 0·33 0·51 0·32 1·39 (0·73)	0·386	·515	·373
4	110·6	108 111 111 111 112	0·08 (0·74) 0·02 0·13 0·03 0	0·184	·550	·404
5	113·6	113 113 114 114 114	0 0·12 0·01 0·14 0	0·054	·061	·062
6	115·8	115 115 116 116 117	0·12 0·28 0 0·18 0·04 (0·02)	0·120	·108	·116
7	117·8	117 118 118 118 118	0 (0·02) 0·05 (0·05) 0·03 (0·06) 0·02 (0·05) 0 (0·06)	0·048	·059	·055
8	119·2	118 118 119 120 121	0·05 (0·05) 0·18 (0·06) 0 0·29 0	0·080	·098	·114

GROUP 8A—*contd.*

r.	$\bar{P}_r$.	P.	R.	$\bar{R}_r$.	d_r.	σ_r.
9	122·2	121 122 122 123 123	0 0·14 0 0 0	0·028	·045	·056
10	124·2	124 124 124 124 125	0 0 0·07 0 0	0·014	·022	·028
11	125·8	125 126 126 126 126	0 0 0 0·03 0	0·006	·010	·010
12	127·0	126 127 127 127 128	0 0·17 0 0·14 0	0·062	·074	·077
13	130·6	129 130 131 131 132	0 0 0 0 0	0·000	·000	·000
14	137·3	134 136 137 138 139 140	0 0·06 0 0 0 0	0·001	·017	·024

of the sub-groups as well as marked irregularity in the progress of the $\bar{R}_r$'s of the group. At the same time the general trend in almost all the groups consisted of a high and slowly falling rainfall at low pressures, followed by a somewhat rapid decrease at medium pressures, shading off slowly to zero rainfall at high pressures. It was therefore clear that neither a straight line nor an algebraic curve of the second or third degree should be selected. On the other hand a curve of the type of the normal curve of errors naturally suggested itself, and we have found that in the case of every one of the 36 groups an equation of the type

$$\tilde{R} = R_0 \cdot 10^{-\kappa(P-P_0)^2}$$

gives a fair, good, or very good approximation to the mean values $\bar{R}_r$ of the sub-groups; $\tilde{R}$ being the predicted rainfall, and R_0, κ, P_0 three constants which were in general different in the different groups.

R_0 is the maximum calculated rainfall and P_0 the pressure at which it occurred, and $\frac{1}{\sqrt{\kappa}}$ is a constant, which determines the relative rate at which the rainfall falls off with increasing pressure.

§ 9. In determining the three constants for a group, P_0 was generally assigned by inspection, after some experience of fitting. Almost invariably it had the same value as, or a lower value than, the lowest value of observed pressure in the group S concerned. Groups 1, A and B winds, 7, B winds, and 8, B winds, are notable exceptions. In group 1 there is a rise of pressure during each of the three days preceding the observation; in group 7 the change is $+ - +$; and in group 8, $+ - 0$; and it has been noticed, as is indeed evident from the plot of the groups, that in weather of these types rainfall occurs with high pressure. In these groups P_0 was chosen in correspondence with the maximum value of the sub-group means of rainfall.

R_0 was adjusted in such a way as to make $\Sigma\tilde{R}$ as nearly equal to $\Sigma\bar{R}_r$ as possible.

The third constant, κ, which, as we have seen, gives the shape of the curve, was determined by trial and error. The final adjustment for a minimum of $\Sigma(\bar{R}_r - \tilde{R})^2$ was done mainly by variation of κ. It was found that κ in the form of $\frac{a}{10^b}$ ($b=3$, 4, or 5) gave the simplest method of calculation in fitting the curve.

In the case of group 8A, for which the numerical data have already been tabulated, the best-fitting curve was

$$\tilde{R} = 0{\cdot}651'' \cdot 10^{-\frac{5}{10{,}000}(P-75)^2}$$

It gave the following results:—

$\bar{P}_r$.	$\bar{R}_r$.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.
92·2	·432	·463	– ·031
101·6	·232	·288	– ·056
106·6	·386	·206	·180
110·6	·184	·151	·033
113·6	·054	·117	– ·063
115·8	·120	·096	·024
117·8	·048	·079	– ·031
119·2	·080	·069	·011
122·2	·028	·050	– ·022
124·2	·014	·040	– ·026
125·8	·006	·033	– ·027
127·0	·062	·029	·033
130·6	0	·019	– ·019
137·3	·001	·007	– ·006

$$\Sigma\bar{R}_r = 1{\cdot}647 \quad \Sigma\bar{R} = 1{\cdot}647 \quad \Sigma(\bar{R}_r - \bar{R}) = 0$$
$$\Sigma(\bar{R}_r - \bar{R})^2 = {\cdot}046{,}588.$$

§ 10. Three measures of the variance of the data were then calculated:—

$$S_1^2 = \sum_r (\bar{R}_r - \bar{R})^2 = {\cdot}046{,}588$$

$$S_2^2 = \sum_r \sum_{n_r} (R - \bar{R}_r)^2 = \sum_r n_r \sigma_r^2$$

where r = number of sub-groups, n_r = number of observations in each sub-group r.

$$= 2{\cdot}541{,}396$$

$$S_3^2 = \sum_r (\bar{R}_r - \bar{R})^2 = {\cdot}260{,}423$$

where $\bar{R}$ is the mean rainfall of the group.

As a measure of the goodness of fit of the curve to the data, the following constant was determined:—

$$g = 1 - \sqrt{\frac{S_1^2}{f_1} \cdot \frac{f_2}{S_2^2}}$$

where $f_1 = r$, $f_2 = N - r$, N being the total number of observations in the group.

It is obvious that the larger the g the better the curve fits the observations.

Since rainfall is not normally distributed we cannot use Fisher's Z-test in order to establish the significance of the goodness of fit. The quantity g, however, may properly be taken as a measure of the fit, as its divergence from unity is small in proportion as the variance of the calculated from

the mean observed values is small relatively to the variance of all the observations.

In the great majority of groups the fit may be regarded as satisfactory. In 23 groups out of the 36, g exceeds 0·7, and it falls below 0·5 in group 14, A winds, only. Even in this case the curve cannot be considered a bad fit for the data. In group 18, A winds, the amount of rain that falls on any one day is most erratic; hence the low value of g in that group also. It is difficult in this case to obtain any formula that will give a good approximation even to the mean rainfall.

§ 11. Two graphs were drawn for each of the 36 groups:—

I. Showing—

(i) The points $(\bar{P}_r, \bar{R}_r)$, namely, the means of the sub-groups.

(ii) The extent of the *mean* deviation of rainfall within each sub-group.

(iii) The best-fitting curve, $\bar{R} = R_0 \cdot 10^{-\kappa(P-P_0)^2}$, to the sub-group means.

II. Showing the frequency of rainy days within each sub-group.

The frequency will range from the maximum of 5 days of rain out of the 5 days in the sub-group down to the minimum of 0, no days of rain in the sub-group. The height of the horizontal line represents the number of rainy days, or the frequency, in each sub-group, and its length indicates the whole range of pressure covered by that sub-group. The dotted vertical lines show the limits of pressure in the sub-group.

For example, in the sub-group $r=4$ of group 8, A winds, the frequency is 4, *i.e.* 4 days of rain out of the maximum 5, and the pressure ranges from 108 to 112.

When observations at the same value of pressure fell into adjacent sub-groups, the number of rainy days at that value of pressure was divided proportionally between the sub-groups concerned. Hence the fractional values of frequency obtained in many cases. If a sub-group contains more than 5 observations the frequency is still entered in the graph as a certain number of rainy days out of a maximum of 5. For example, in the sub-group $r=14$, of group 8, A winds, there is one rainy day out of 6, therefore the frequency is entered as $\frac{5}{6}$ out of 5 days.

It can be seen from the plot of these graphs, as is indeed to be expected, that the tendency of the frequency is from the maximum of 5 days of rain to the minimum of 0 days of rain out of the 5 in the sub-group as the pressure increases from low to high values. In most cases this downward tendency of the frequency is fairly irregular.

Tables were made out for each of the 36 groups, showing:—

(i) $\bar{P}_r$, the sub-group means of pressure.

(ii) $\bar{R}_r$, the sub-group means of rainfall.

(iii) d_r, the mean deviation of rainfall within each sub-group.

(iv) σ_r, the standard deviation of rainfall within each sub-group.

(v) $\bar{R}$, the values of R calculated from the fitted curve.

(vi) $\bar{R}_r - \bar{R}$, the deviation of the sub-group means from the calculated or prediction values of rainfall.

(vii) The variances S_1^2, S_2^2, S_3^2, and g.

§ 12. We have now an equation expressing the most probable amount of rainfall at Cape Town during the four winter months May to August in terms of atmospheric pressure for each of the 36 pressure-rainfall groups, based on the experience of the 19 years 1916–1934.

Hence being given any reading of the barometer at 08·30, and knowing the change in pressure over the three days preceding the observation and the direction of the wind at the time of observation, we can read off from the corresponding graph the calculated value of mean rainfall at that value of pressure. The frequency of rainy days at that pressure can also be obtained, and will act as a guide to the probability of any rain falling at all. The mean deviations give a picture of the extent to which the amount of rain varies within each sub-group, and these should also be taken into account. Thus we can obtain a simple method of forecasting the most probable amount of rain which will fall during the 24 hours following an observation.

Let us consider as examples two recent observations taken during July 1935. On 9th July the barometric pressure at 08·30 was 30·11 inches, *i.e.* 111 on our scale, the change in pressure over the preceding three days was $- \ - \ -$, and the wind direction at 08·30 was in the A group. Turning to the graphs for group 18, A winds, therefore, and reading off from the curve, we find the prediction value of R for P = 111 to be 0·19 inches. Also the frequency at P = 111 is $3\frac{1}{3}$ days out of 5—that is, during the 19 years' experience of weather of this type, rain fell on $3\frac{1}{3}$ out of every 5, or 2 out of every 3 days, having the pressure at 08·30 equal to 30·11 inches. The mean deviation of the sub-group into which P = 111 falls is 0·34 inches. We can therefore say that it is practically certain that rain will fall in the next 24 hours, and the amount will be about 0·2 inches. The actual rainfall registered on that day was 0·28 inches.

On 10th July the barometric reading was 30·27 inches, *i.e.* 127 on our scale, the change of pressure was $- \ - \ +$, and the wind was again in the A group. From the graphs for group 16, A winds, the most probable value of rainfall is 0·07 inches, and the frequency is 1 rainy day out of 5. Thus we can say that it is unlikely that any rain will fall within the next 24 hours. The rain registered on that day was nil.

In both these cases, therefore, our forecast was correct within a permissible margin of error.

The following tables show the rainfall registered during May and June 1935, and the amount of rain and the frequency calculated from the graphs:—

MAY 1935.

R = actual rainfall.	f = frequency (in days out of 5 days).	$\bar{R}$ = calculated rainfall.
0	1	0·03
0·34	2	0·17
0	2	0·05
0	2	0·03
0·11	3	0·16
0	2	0·01
0	0	0·01
0	1½	0·08
0·01	5	0·32
0·12	3⅔	0·13
0	2	0·05
0	0	0·01
0	1	0·00
0	2	0·02
0	0	0·02
0	2	0·00
0	2	0·02
0	⅔	0·05
0·50	4	0·21
0	4½	0·07
0	1⅔	0·07
0·16	2½	0·16
0·72	4⅓	0·29
0·86	4⅓	0·15
0·58	5	0·59
0·08	2	0·04
0	0	0·00
0	1	0·03
0	0	0·00
0	½	0·01
0	½	0·01

JUNE 1935.

R = actual rainfall.	f = frequency (in days out of 5 days).	$\bar{R}$ = calculated rainfall.
0	0	0·02
0	0	0·01
0	1	0·01
0	2	0·03
0	0	0·02
0	½	0·00
0	0	0·01
0·04	1	0·02
0·20	2	0·12
0·02	2	0·06
0	0	0·02
0	1	0·00
0	1½	0·01
0	0	0·04
0	0	0·02
0·28	⅔	0·05
0·11	0	0·04
0	0	0·00
0	½	0·00
0	2⅓	0·02
0·30	5	0·47
0·10	5	0·39
0·02	3	0·03
0	2	0·01
0	0	0·00
0	1	0·08
0	2½	0·06
0·05	1⅔	0·01
0	1⅓	0·07
0	0	0·00

§ 13. *Summary.*—The purpose of the investigation was to discover whether, for various types of winter weather at Cape Town, the relationship which should exist between the daily barometric pressure and the amount of ensuing rainfall could be put in the form of some simple mathematical function.

The observations, taken at Portswood Road, Cape Town, during May, June, July, and August of the years 1916 to 1934 inclusive, were classified according to (i) the change in the pressure during the three days preceding the day of observation, and (ii) whether the prevailing wind at the time of observation lay in the northern or the southern portion of a depression. The data was thus divided into 36 groups of weather of different types.

Each of these 36 groups, containing values of pressure and corresponding rainfall, was then arranged in descending order of pressure, and divided into sub-groups of 5 each. The sub-group means, $\bar{P}_r$ and $\bar{R}_r$, and the deviations of rainfall, d_r and σ_r, within the sub-groups were calculated.

A curve of the form $\tilde{R} = R_0 \cdot 10^{-\kappa(P-P_0)^2}$ was fitted to the sub-group means of each group. This curve represents the most probable amount of mean rainfall at each value of pressure in that group.

A measure of the goodness of fit of the curve to the data was calculated. Its divergence from unity is small in proportion as the sum of the squared deviations of the calculated from the observed mean rainfall is small relatively to the total variance of the rainfall within the sub-groups. In 23 out of the 36 groups this measure exceeds 0·7, and it falls below 0·5 in one case only.

Graphs were drawn for each of the 36 groups: one showing the sub-group means and the best-fitting curve to these means, and one showing the frequency of rainy days within each sub-group.

The most probable amount of rainfall following an observation can be predicted from the graphs.

Tables for the 36 Groups.

Showing:—

(i) Fitted exponential curve.
(ii) $\bar{P}_r$, Sub-group means of P = pressure.
(iii) $\bar{R}_r$, Sub-group means of R = rainfall.
(iv) d_r, Mean deviation of R within each sub-group.
(v) σ_r, Standard deviation of R within each sub-group.
(vi) $\tilde{R}$, Prediction values of R from curve, for each sub-group mean.
(vii) $\bar{R}_r - \tilde{R}$, Deviation of sub-group means of R from curve.
(viii) Variances:—

$$S_1^2 = \sum_r (\bar{R}_r - \tilde{R})^2.$$

$$S_2^2 = \sum_r \sum_n (R - \bar{R}_r)^2 = \sum_r n\sigma_r^2.$$

$$S_3^2 = \sum_r (\bar{R}_r - \bar{R})^2.$$

$$g = 1 - \sqrt{\frac{S_1^2}{f_1} \cdot \frac{f_2}{S_2^2}}. \qquad \text{(See § 10.)}$$

Tables.

Group I, + + + *A* Winds.

$$\bar{R} = 0{\cdot}118'' \cdot 10^{-\frac{43}{10,000}(P-130)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
120·0	·024	·038	·048	·044	− ·020	$S_1^2 = {\cdot}003,160$
129·6	·130	·136	·154	·118	·012	$S_2^2 = {\cdot}261,113$
131·8	·084	·097	·103	·114	− ·030	$S_3^2 = {\cdot}012,052$
137·0	·084	·095	·100	·073	·011	
141·6	·024	·038	·048	·031	− ·007	$g = {\cdot}9280$
146·2	·004	·006	·008	·009	− ·005	
152·9	·040	·046	·048	·001	·039	

$\Sigma\bar{R}_r = {\cdot}390''$ $\Sigma\bar{R} = {\cdot}390''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

Group I, + + + *B* Winds.

$$\bar{R} = 0{\cdot}080'' \cdot 10^{-\frac{13}{1000}(P-143)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
121·2	0	0	0	0	0	$S_1^2 = {\cdot}001,335$
129·4	·002	·003	·004	0	·002	$S_2^2 = {\cdot}189,390$
135·8	·024	·082	·061	·017	·007	$S_3^2 = {\cdot}007,179$
140·2	·034	·104	·070	·063	− ·029	
144·2	·098	·158	·171	·077	·021	$g = {\cdot}8321$
156·4	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}158''$ $\Sigma\bar{R} = {\cdot}157''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}001''$

Group 2, + + 0 *A* Winds.

$$\bar{R} = 0{\cdot}072'' \cdot 10^{-\frac{4}{10,000}(P-110)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
117·8	·090	·088	·095	·068	·022	$S_1^2 = {\cdot}007,869$
122·4	·062	·085	·069	·062	0	$S_2^2 = {\cdot}364,650$
124·4	·018	·051	·049	·059	− ·041	$S_3^2 = {\cdot}010,913$
128·2	·066	·102	·127	·053	·013	
130·4	·104	·150	·141	·049	·055	$g = {\cdot}7062$
131·8	·030	·076	·091	·046	− ·016	
133·2	·006	·010	·012	·044	− ·038	
135·8	·018	·022	·022	·039	− ·021	
142·0	·042	·067	·084	·028	·014	
146·4	·034	·054	·068	·021	·013	
156·6	·008	·010	·012	·010	− ·002	

$\Sigma\bar{R}_r = {\cdot}478''$ $\Sigma\bar{R} = {\cdot}479''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}001''$

GROUP 2, + + 0 *B* WINDS.

$$\bar{R} = 0{\cdot}004'' \cdot 10^{-\frac{6}{10,000}(P-120)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
122·2	0	0	0	·004	– ·004	$S_1^2 = {\cdot}000{,}177$
126·2	0	0	0	·004	– ·004	$S_2^2 = {\cdot}012{,}182$
129·8	·012	·019	·024	·004	·008	$S_3^2 = {\cdot}000{,}197$
132·4	·004	·006	·008	·003	·001	
134·4	0	0	0	·003	– ·003	$g = {\cdot}7540$
135·6	·010	·028	·025	·003	·007	
137·4	·004	·013	·015	·003	·001	
138·2	0	0	0	·003	– ·003	
139·0	0	0	0	·002	– ·002	
141·0	0	0	0	·002	– ·002	
143·2	0	0	0	·002	– ·002	
147·3	·001	·017	·026	·001	0	

$\Sigma\bar{R}_r = {\cdot}031''$ $\Sigma\bar{R} = {\cdot}034''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}003''$

GROUP 3, + + – *A* WINDS.

$$\bar{R} = 0{\cdot}572'' \cdot 10^{-\frac{53}{100,000}(P-85)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
95·2	·620	·332	·443	·504	·116	$S_1^2 = {\cdot}165{,}301$
105·4	·126	·131	·151	·344	– ·218	$S_2^2 = 3{\cdot}109{,}300$
109·2	·114	·169	·131	·280	– ·166	$S_3^2 = {\cdot}380{,}746$
112·0	·270	·131	·125	·235	·035	
115·0	·458	·361	·370	·191	·267	$g = {\cdot}5389$
116·8	·158	·290	·257	·167	– ·009	
119·2	·138	·221	·276	·137	·001	
121·8	·094	·122	·155	·110	– ·016	
125·2	·058	·161	·155	·080	– ·022	
128·0	·108	·275	·207	·060	·048	
133·4	0	0	0	·033	– ·033	
145·6	0	0	0	·006	– ·006	

$\Sigma\bar{R}_r = 2{\cdot}144''$ $\Sigma\bar{R} = 2{\cdot}147''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}003''$

GROUP 3, + + − *B* WINDS.

$$\bar{R} = 0{\cdot}359'' \cdot 10^{-\frac{105}{100{,}000}(P-85)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
99·8	·214	·282	·358	·211	·003	$S_1^2 = {\cdot}002{,}674$
111·4	·040	·064	·080	·067	− ·027	$S_2^2 = {\cdot}778{,}480$
115·6	·078	·119	·137	·037	·041	$S_3^2 = {\cdot}043{,}200$
118·0	·020	·052	·033	·026	− ·006	
120·4	·006	·021	·020	·017	− ·011	$g = {\cdot}8807$
122·8	·012	·019	·024	·011	·001	
125·2	·002	·003	·004	·007	− ·005	
127·2	0	0	0	·005	− ·005	
128·6	·006	·009	·007	·004	·002	
129·8	·002	·004	·005	·003	− ·001	
131·6	·006	·007	·008	·002	·004	
134·0	0	0	0	·001	− ·001	
137·0	·006	·010	·012	·001	·005	
143·4	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}392''$ $\Sigma\bar{R} = {\cdot}392''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 4, + 0 + *A* WINDS.

$$\bar{R} = 0{\cdot}488'' \cdot 10^{-\frac{15}{1000}(P-115)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
117·8	·310	·452	·567	·372	− ·062	$S_1^2 = {\cdot}016{,}542$
121·8	·036	·035	·037	·099	− ·063	$S_2^2 = 1{\cdot}739{,}695$
128·8	·002	·006	·005	·001	·001	$S_3^2 = {\cdot}068{,}997$
133·2	·090	·130	·156	0	·090	
136·8	·022	·027	·024	0	·022	$g = {\cdot}8050$
144·4	·012	·015	·012	0	·012	

$\Sigma\bar{R}_r = {\cdot}472''$ $\Sigma\bar{R} = {\cdot}472''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 4, + 0 + ${}_{,}$*B* WINDS.

$$\bar{R} = 0{\cdot}033'' \cdot 10^{-\frac{35}{100{,}000}(P-105)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
118·8	·028	·045	·056	·028	0	$S_1^2 = {\cdot}000{,}186$
128·4	·022	·031	·039	·021	·001	$S_2^2 = {\cdot}038{,}344$
134·2	·026	·052	·036	·017	·009	$S_3^2 = {\cdot}000{,}471$
137·2	·016	·042	·029	·014	·002	
141·5	·001	·019	·027	·011	− ·010	$g = {\cdot}8573$

$\Sigma\bar{R}_r = {\cdot}093''$ $\Sigma\bar{R} = {\cdot}091''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}002''$

GROUP 5, + 0 0 *A* WINDS.

$$\bar{R} = 0{\cdot}125'' {\cdot} 10^{-\frac{47}{100,000}(P-100)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
106·0	·122	·050	·057	·120	·002	$S_1^2 =$ ·024,943
112·4	·154	·185	·236	·106	·048	$S_2^2 =$ 1·246,935
117·2	·034	·073	·064	·091	– ·057	$S_3^2 =$ ·037,822
119·6	·062	·121	·136	·082	– ·020	
121·4	·106	·251	·218	·076	·030	$g =$ ·7171
124·0	·018	·054	·039	·067	– ·049	
126·2	·014	·055	·039	·059	– ·045	
128·6	·130	·260	·231	·052	·078	
130·6	·092	·210	·197	·045	·047	
132·2	·016	·023	·027	·041	– ·025	
134·0	·094	·122	·155	·036	·058	
136·0	·010	·011	·018	·031	– ·021	
138·0	·002	·005	·006	·026	– ·024	
142·0	0	0	0	·019	– ·019	
$\Sigma\bar{R}_r = {\cdot}854''$				$\Sigma\bar{R} = {\cdot}851''$	$\Sigma(\bar{R}_r - \bar{R}) = {\cdot}003''$	

GROUP 5, + 0 0 *B* WINDS.

$$\bar{R} = 0{\cdot}005'' {\cdot} 10^{-\frac{4}{10,000}(P-95)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
110·6	·002	·003	·004	·004	·002	$S_1^2 =$ ·000,039
117·4	·002	·003	·004	·003	– ·001	$S_2^2 =$ ·001,960
120·6	·006	·007	·008	·003	·003	$S_3^2 =$ ·000,056
124·0	·006	·010	·012	·002	·004	
126·0	·002	·008	·006	·002	0	$g =$ ·7099
128·8	·002	·008	·006	·002	0	
129·8	·002	·003	·004	·002	0	
131·0	·004	·006	·008	·002	·002	
132·6	0	0	0	·001	– ·001	
133·8	0	0	0	·001	– ·001	
135·8	0	0	0	·001	– ·001	
137·4	0	0	0	·001	– ·001	
142·9	0	0	0	·001	– ·001	
$\Sigma\bar{R}_r = 026''$				$\Sigma\bar{R} = {\cdot}025''$	$\Sigma(\bar{R}_r - \bar{R}) = {\cdot}001''$	

GROUP 6, + 0 − *A* WINDS.

$$\tilde{R} = 0{\cdot}536'' \cdot 10^{-\frac{3}{10{,}000}(P-70)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\tilde{R}$.	$\bar{R}_r - \tilde{R}$.	Variances.
82·6	·428	·269	·346	·480	− ·052	$S_1^2 =$ ·114,405
96·2	·492	·370	·434	·334	·158	$S_2^2 =$ 4·806,448
100·6	·132	·211	·161	·281	− ·149	$S_3^2 =$ ·383,286
101·8	·316	·163	·151	·267	·049	
103·2	·280	·251	·202	·250	·030	$g =$ ·6860
105·6	·322	·440	·424	·223	·099	
107·6	·268	·216	·145	·202	·066	
109·8	·210	·132	·147	·179	·031	
111·6	·102	·108	·121	·162	− ·060	
113·0	·090	·106	·171	·149	− ·059	
114·6	·042	·067	·084	·136	− ·094	
115·8	·074	·102	·127	·126	− ·052	
116·6	·150	·233	·262	·120	·030	
117·8	·086	·198	·216	·111	− ·025	
119·8	·062	·091	·088	·097	− ·035	
122·0	·016	·026	·032	·083	− ·067	
123·2	·038	·061	·076	·076	− ·038	
125·8	·128	·205	·256	·062	·066	
128·0	·170	·208	·267	·052	·118	
133·2	·012	·019	·024	·034	− ·022	
140·25	·025	·044	·066	·018	·007	

$\Sigma\bar{R}_r = 3{\cdot}443''$ $\Sigma\tilde{R} = 3{\cdot}442''$ $\Sigma(\bar{R}_r - \tilde{R}) = {\cdot}001''$

GROUP 6, + 0 − *B* WINDS.

$$\tilde{R} = 0{\cdot}534'' \cdot 10^{-\frac{7}{10{,}000}(P-70)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\tilde{R}$.	$\bar{R}_r - \tilde{R}$.	Variances.
84·2	·386	·181	·195	·386	0	$S_1^2 =$ ·003,723
107·8	·034	·042	·054	·053	− ·019	$S_2^2 =$ ·288,000
112·4	·002	·003	·004	·029	− ·027	$S_3^2 =$ ·136,609
115·0	·060	·074	·076	·020	·040	
116·6	·020	·068	·051	·016	·004	$g =$ ·7709
117·8	0	0	0	·013	− ·013	
119·0	·012	·015	·019	·011	·001	
120·4	0	0	0	·009	− ·009	
121·6	0	0	0	·007	− ·007	
123·2	0	0	0	·006	− ·006	
124·4	·028	·096	·071	·005	·023	
126·4	·014	·054	·052	·003	·011	
128·2	0	0	0	·002	− ·002	
130·4	·002	·003	·004	·001	·001	
132·0	·006	·010	·012	·001	·005	
134·4	0	0	0	·001	− ·001	
139·2	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}564''$ $\Sigma\tilde{R} = {\cdot}563''$ $\Sigma(\bar{R}_r - \tilde{R}) = {\cdot}001''$

GROUP 7, + − + *A* WINDS.

$$\tilde{R} = 0{\cdot}413''{\cdot}10^{-\frac{51}{100,000}(P-85)^2}$$

$\bar{P}_r$	$\bar{R}_r$.	d_r.	σ_r.	$\tilde{R}$.	$\bar{R}_r - \tilde{R}$.	Variances.
95·8	·346	·207	·230	·360	− ·014	$S_1^2 =$ ·027,427
108·8	·156	·111	·138	·212	− ·056	$S_2^2 =$ 1·541,124
111·8	·272	·190	·238	·178	·094	$S_3^2 =$ ·152,355
114·2	·160	·259	·271	·152	·008	
116·8	·228	·290	·292	·126	·102	$g =$ ·7281
120·4	·072	·085	·098	·095	− ·023	
121·4	·038	·051	·051	·087	− ·049	
124·0	·036	·035	·045	·069	− ·033	
127·2	·044	·076	·055	·051	− ·007	
130·8	·014	·057	·042	·035	− ·021	
133·8	·038	·036	·036	·025	·013	
136·7	·010	·018	·017	·018	− ·008	
140·0	·005	·008	·015	·012	− ·007	

$\Sigma\bar{R}_r = 1{\cdot}419''$ $\Sigma\tilde{R} = 1{\cdot}420''$ $\Sigma(\bar{R}_r - \tilde{R}) = -{\cdot}001''$

GROUP 7, + − + *B* WINDS.

$$\tilde{R} = 0{\cdot}018''{\cdot}10^{-\frac{16}{10,000}(P-115)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\tilde{R}$.	$\bar{R}_r - \tilde{R}$.	Variances.
110·4	·034	·046	·059	·044	− ·010	$S_1^2 =$ ·000,399
117·4	·050	·060	·068	·047	·003	$S_2^2 =$ ·096,170
122·6	·046	·074	·092	·039	·007	$S_3^2 =$ ·002,342
127·0	·040	·048	·051	·028	·012	
133·6	·004	·006	·008	·013	− ·009	$g =$ ·8712
140·6	0	0	0	·004	− ·004	

$\Sigma\bar{R}_r = {\cdot}174''$ $\Sigma\tilde{R} = {\cdot}175''$ $\Sigma(\bar{R}_r - \tilde{R}) = -{\cdot}001''$

Group 8, + − 0 *A* Winds.

$$\bar{R} = 0{\cdot}651'' \cdot 10^{-\frac{5}{10,000}(P-75)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
92·2	·432	·330	·352	·463	− ·031	$S_1^2 =$ ·046,588
101·6	·232	·186	·195	·288	− ·056	$S_2^2 =$ 2·541,396
106·6	·386	·515	·373	·206	·180	$S_3^2 =$ ·260,423
110·6	·184	·550	·404	·151	·033	
113·6	·054	·061	·062	·117	− ·063	$g =$ ·7268
115·8	·120	·108	·116	·096	·024	
117·8	·048	·059	·055	·079	− ·031	
119·2	·080	·098	·114	·069	·011	
122·2	·028	·045	·056	·050	− ·022	
124·2	·014	022	·028	·040	− ·026	
125·8	·006	·010	·012	·033	− ·027	
127·0	·062	·074	·077	·029	·033	
130·6	0	0	0	·019	− ·019	
137·3	·001	·017	·024	·007	− ·006	

$\Sigma\bar{R}_r = 1{\cdot}647''$ $\Sigma\bar{R} = 1{\cdot}647''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

Group 8, + − 0 *B* Winds.

$$\bar{R} = 0{\cdot}091'' \cdot 10^{-\frac{1}{1000}(P-110)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
103·8	·062	·095	·119	·064	− ·002	$S_1^2 =$ ·000,298
114·0	·080	·096	·098	·079	·001	$S_2^2 =$ ·192,210
117·6	·052	·079	·099	·053	− ·001	$S_3^2 =$ ·006,320
121·6	·038	·061	·076	·026	·012	
124·2	·002	·003	·004	·014	− ·012	$g =$ ·9227
131·0	·004	·006	·008	·002	·002	
136·5	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}238''$ $\Sigma\bar{R} = {\cdot}238''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 9, + − − *A* WINDS.

$$\bar{R} = 0{\cdot}744'' \cdot 10^{-\frac{22}{100,000}(P-60)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
75·2	·662	·270	·329	·662	0	$S_1^2 =$ ·385,904
88·0	·640	·336	·454	·500	·140	$S_2^2 =$ 12·398,715
93·2	·284	·145	·170	·426	− ·142	$S_3^2 =$ ·796,060
94·8	·260	·115	·117	·403	− ·143	
97·6	·544	·382	·490	·364	·180	$g =$ ·6472
99·6	·416	·121	·170	·336	·080	
101·2	·120	·128	·126	·315	− ·195	
102·6	·248	·237	·273	·297	− ·049	
104·2	·296	·154	·187	·277	·019	
105·8	·268	·279	·293	·257	·011	
106·8	·164	·167	·236	·245	− ·081	
107·2	·174	·122	·194	·241	− ·067	
109·4	·384	·502	·524	·216	·168	
110·6	·156	·285	·234	·203	− ·047	
111·8	·138	·179	·135	·191	− ·053	
113·8	·184	·141	·116	·172	·012	
115·4	·084	·220	·160	·157	− ·073	
116·8	·570	·907	1·057	·145	·425	
118·2	·056	·090	·112	·134	− ·078	
120·0	·044	·118	·110	·120	− ·076	
122·0	·128	·193	·144	·106	·022	
131·2	0	0	0	·057	− ·057	

$\Sigma\bar{R}_r = 5{\cdot}820''$ $\Sigma\bar{R} = 5{\cdot}824''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}004''$

GROUP 9, + − − *B* WINDS.

$$\bar{R} = 0{\cdot}259'' \cdot 10^{-\frac{4}{1000}(P-95)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
99·2	·228	·295	·319	·220	·008	$S_1^2 =$ ·012,775
103·8	·054	·221	·162	·127	− ·073	$S_2^2 =$ ·900,175
106·4	·056	·221	·161	·078	− ·022	$S_3^2 =$ ·046,536
110·2	0	0	0	·031	− ·031	
112·4	·044	·066	·083	·016	·028	$g =$ ·7668
116·0	·072	·103	·130	·004	·068	
118·0	·002	·003	·004	·002	0	
121·0	·024	·038	·048	·001	·023	
122·2	0	0	0	0	0	
124·4	0	0	0	0	0	
128·0	0	0	0	0	0	
134·3	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}480''$ $\Sigma\bar{R} = {\cdot}479''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}001''$

Group 10, − + + *A* Winds.

$$\bar{R} = 0{\cdot}716''{\cdot}10^{-\frac{85}{100,000}(P-95)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
106·8	·592	·474	·508	·545	·047	$S_1^2 =$ ·052,209
116·6	·116	·138	·176	·287	−·171	$S_2^2 =$ 2·415,452
122·8	·214	·220	·221	·158	·056	$S_3^2 =$ ·312,831
124·8	·112	·192	·199	·126	−·014	
126·6	·064	·097	·090	·101	−·037	$g =$ ·7017
128·8	·124	·141	·172	·077	·047	
130·2	·008	·012	·014	·063	−·055	
131·2	·026	·073	·047	·055	−·029	
132·8	·024	·069	·048	·044	−·020	
134·0	·024	·061	·093	·036	−·012	
135·2	·080	·154	·175	·030	·050	
137·0	·088	·119	·122	·023	·065	
138·0	·050	·029	·046	·019	·031	
139·8	·010	·012	·015	·014	−·004	
141·6	0	0	0	·010	−·010	
146·5	·030	·051	·059	·004	·026	
154·7	·032	·047	·046	·001	·031	

$\Sigma\bar{R}_r = 1{\cdot}594''$ $\Sigma\bar{R} = 1{\cdot}593''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}001''$

Group 10, − + + *B* Winds.

$$\bar{R} = 0{\cdot}074''{\cdot}10^{-\frac{15}{10,000}(P-110)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
114·8	·082	·087	·113	·068	·014	$S_1^2 =$ ·005,189
123·4	·006	·010	·012	·040	−·034	$S_2^2 =$ ·214,045
127·4	·002	·003	·004	·026	−·024	$S_3^2 =$ ·010,992
131·6	0	0	0	·015	−·015	
133·6	·002	·003	·004	·011	−·009	$g =$ ·6862
134·4	·058	·186	·138	·010	·048	
136·0	·030	·104	·102	·007	·023	
137·8	0	0	0	·005	−·005	
139·8	0	0	0	·003	−·003	
141·0	·002	·003	·004	·003	−·001	
142·4	0	0	0	·002	−·002	
144·0	0	0	0	·001	−·001	
145·4	·010	·016	·020	·001	·009	
146·6	0	0	0	·001	−·001	
148·4	0	0	0	0	0	
151·7	0	0	0	0	0	

$\Sigma\bar{R}_r = {\cdot}192''$ $\Sigma\bar{R} = {\cdot}193''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}001''$

GROUP 11, − + 0 *A* WINDS.

$$\bar{R} = 0{\cdot}350'' \cdot 10^{-\frac{47}{100,000}(P-90)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
102·6	·318	·178	·208	·295	·023	$S_1^2 = {\cdot}055,920$
108·2	·360	·237	·228	·245	·115	$S_2^2 = 1{\cdot}488,035$
111·2	·052	·115	·087	·215	− ·163	$S_3^2 = {\cdot}152,524$
115·8	·142	·106	·114	·170	− ·028	
118·4	·156	·166	·214	·146	·010	$g = {\cdot}6158$
121·4	·132	·145	·154	·120	·012	
124·0	·042	·059	·061	·100	− ·058	
125·6	·122	·192	·229	·089	·033	
127·8	·132	·143	·148	·075	·057	
129·0	·040	·094	·090	·067	− ·027	
130·6	·132	·151	·150	·059	·073	
134·0	·030	·048	·060	·043	− ·013	
139·0	·002	·003	·004	·026	− ·024	
149·25	0	0	0	·008	− ·008	

$\Sigma\bar{R}_r = 1{\cdot}660''$ $\Sigma\bar{R} = 1{\cdot}658''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}002''$

GROUP 11, − + 0 *B* WINDS.

$$\bar{R} = 0{\cdot}078'' \cdot 10^{-\frac{2}{1000}(P-110)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
114·2	·080	·128	·160	·072	·008	$S_1^2 = {\cdot}005,394$
117·8	·026	·042	·052	·059	− ·026	$S_2^2 = {\cdot}311,725$
121·6	·094	·138	·173	·042	·052	$S_3^2 = {\cdot}011,464$
125·6	0	0	0	·025	− ·025	
129·4	·002	·003	·004	·014	− ·012	$g = {\cdot}7402$
131·4	0	0	0	·009	− ·009	
133·8	·032	·051	·064	·006	·026	
136·8	0	0	0	·003	− ·003	
139·4	0	0	0	·001	− ·001	
142·0	0	0	0	·001	− ·001	

$\Sigma\bar{R}_r = {\cdot}234''$ $\Sigma\bar{R} = {\cdot}232''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}002''$

GROUP 12, − + − *A* WINDS.

$$\bar{R} = 0{\cdot}598'' \cdot 10^{-\frac{4}{10,000}(P-75)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
80·2	·626	·358	·452	·583	·043	$S_1^2 =$ ·115,055
94·2	·418	·262	·289	·426	− ·008	$S_2^2 =$ 3·160,775
98·8	·126	·119	·120	·355	− ·229	$S_3^2 =$ ·430,171
103·6	·470	·272	·287	·282	·188	
107·6	·290	·200	·251	·225	·064	$g =$ ·6150
109·6	·120	·204	·164	·199	− ·079	
112·4	·134	·123	·095	·165	− ·031	
116·0	·064	·027	·036	·127	− ·063	
118·4	·112	·154	·168	·106	·006	
119·6	·092	·175	·181	·096	− ·004	
121·6	·162	·206	·245	·081	·081	
123·6	·076	·131	·122	·068	·008	
126·0	·104	·133	·107	·054	·050	
132·8	0	0	0	·028	− ·028	

$\Sigma\bar{R}_r = 2{\cdot}794''$ $\qquad$ $\Sigma\bar{R} = 2{\cdot}795''$ $\quad$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}001''$

GROUP 12, − + − *B* WINDS.

$$\bar{R} = 0{\cdot}042'' \cdot 10^{-\frac{1}{1000}(P-95)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
105·6	·040	·060	·075	·032	·008	$S_1^2 =$ ·000,574
113·8	·010	·020	·014	·019	− ·009	$S_2^2 =$ ·047,105
117·2	·032	·053	·060	·014	·018	$S_3^2 =$ ·001,763
121·6	0	0	0	·008	− ·008	
124·6	0	0	0	·006	− ·006	$g =$ ·7832
130·2	0	0	0	·002	− ·002	
136·25	0	0	0	·001	− ·001	

$\Sigma\bar{R}_r = {\cdot}082''$ $\qquad$ $\Sigma\bar{R} = {\cdot}082''$ $\quad$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

Group 13, − 0 + *A* Winds.

$$\bar{R} = 0{\cdot}562'' \cdot 10^{-\frac{67}{100{,}000}(P-90)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
102·0	·506	·194	·206	·450	·056	$S_1^2 =$ ·091,479
112·4	·110	·098	·076	·259	− ·149	$S_2^2 =$ 1·719,150
116·0	·322	·302	·284	·198	·124	$S_3^2 =$ ·256,639
117·6	·122	·163	·158	·174	− ·052	
118·2	·114	·128	·165	·165	− ·051	$g =$ ·5386
119·4	·020	·032	·032	·148	− ·128	
122·2	·098	·203	·146	·114	− ·016	
123·8	·110	·167	·131	·096	·014	
124·8	·116	·095	·113	·087	·029	
126·2	·032	·045	·052	·074	− ·042	
127·2	·020	·033	·032	·066	− ·046	
128·2	·134	·187	·166	·059	·075	
129·8	·150	·298	·217	·049	·101	
131·0	·056	·056	·084	·042	·014	
132·4	·006	·007	·008	·035	− ·029	
134·6	·106	·103	·137	·026	·080	
137·8	·042	·063	·079	·017	·025	
146·6	0	0	0	·004	− ·004	

$\Sigma\bar{R}_r = 2{\cdot}064''$ $\Sigma\bar{R} = 2{\cdot}063''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}001''$

Group 13, − 0 + *B* Winds.

$$\bar{R} = 0{\cdot}175'' \cdot 10^{-\frac{4}{1000}(P-110)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
113·6	·150	·120	·157	·155	− ·005	$S_1^2 =$ ·000,454
124·0	·022	·026	·031	·029	− ·007	$S_2^2 =$ ·135,459
126·8	·004	·006	·008	·013	− ·009	$S_3^2 =$ ·018,616
129·2	·002	·003	·004	·006	− ·004	
132·8	0	0	0	·001	− ·001	$g =$ ·8826
134·8	0	0	0	·001	− ·001	
137·2	·006	·016	·014	0	·006	
139·2	·014	·026	·025	0	·014	
143·5	·007	·024	·022	0	·007	

$\Sigma\bar{R}_r = {\cdot}205''$ $\Sigma\bar{R} = {\cdot}205''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 14, – 0 0 *A* WINDS.

$$\bar{R} = 0{\cdot}425''{\cdot}10^{-\frac{8}{10,000}(P-90)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
98·2	·280	·220	·252	·375	– ·095	$S_1^2 =$ ·187,981
105·4	·598	·222	·250	·275	·323	$S_2^2 =$ 2·165,120
109·0	·050	·048	·051	·219	– ·169	$S_3^2 =$ ·389,306
110·6	·082	·078	·090	·194	– ·112	
112·4	·252	·114	·147	·169	·083	$g =$ ·3985
114·2	·200	·294	·353	·145	·055	
115·4	·096	·112	·083	·129	– ·033	
117·2	·230	·272	·310	·109	·121	
119·2	·024	·055	·037	·088	– ·064	
120·8	·048	·064	·048	·074	– ·026	
122·2	·044	·045	·073	·063	– ·019	
123·0	·044	·044	·129	·057	– ·013	
123·2	·034	·045	·117	·056	– ·022	
126·4	0	0	0	·037	– ·037	
130·4	·002	·003	·004	·021	– ·019	
134·3	·027	·045	·059	·011	·016	
136·5	·013	·040	·042	·008	·005	
140·5	·013	·031	·035	·004	·009	

$\Sigma\bar{R}_r = 2{\cdot}037''$ $\Sigma\bar{R} = 2{\cdot}034''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}003''$

GROUP 14, – 0 0 *B* WINDS.

$$\bar{R} = 0{\cdot}083''{\cdot}10^{-\frac{8}{10,000}(P-100)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
107·2	·124	·149	·179	·075	·049	$S_1^2 =$ ·026,276
112·2	·002	·003	·004	·063	– ·061	$S_2^2 =$ ·719,874
116·2	0	0	0	·051	– ·051	$S_3^2 =$ ·031,558
118·8	·014	·011	·012	·043	– ·029	
121·4	·160	·256	·320	·036	·124	$g =$ ·6136
125·0	·046	·070	·087	·026	·020	
127·4	0	0	0	·021	– ·021	
129·0	0	0	0	·018	– ·018	
131·6	0	0	0	·013	– ·013	
134·6	·008	·033	·024	·009	– ·001	
138·3	·007	·031	·032	·006	·001	

$\Sigma\bar{R}_r = {\cdot}361''$ $\Sigma\bar{R} = {\cdot}361''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 15, – 0 – *A* WINDS.

$$\bar{R} = 0{\cdot}760'' \cdot 10^{-\frac{35}{100,000}(P-70)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
79·6	·718	·367	·276	·706	·012	$S_1^2 =$ ·106,248
87·0	·610	·429	·378	·602	·008	$S_2^2 =$ 5·136,130
93·0	·450	·247	·253	·496	– ·046	$S_3^2 =$ ·625,189
98·2	·318	·214	·193	·400	– ·082	
101·0	·352	·236	·197	·350	·002	$g =$ ·7123
102·6	·350	·456	·303	·323	·027	
104·4	·486	·376	·440	·293	·193	
106·6	·206	·153	·169	·258	– ·052	
109·2	·212	·263	·275	·220	– ·008	
111·8	·380	·516	·506	·186	·194	
114·2	·130	·145	·108	·157	– ·027	
116·6	·026	·093	·090	·132	– ·106	
122·0	·026	·042	·052	·086	– ·060	
126·6	0	0	0	·057	– ·057	

$\Sigma\bar{R}_r = 4{\cdot}264''$ $\Sigma\bar{R} = 4{\cdot}266''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}002''$

GROUP 15, – 0 – *B* WINDS.

$$\bar{R} = 0{\cdot}240'' \cdot 10^{-\frac{25}{10,000}(P-100)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
105·8	·204	·290	·299	·198	·006	$S_1^2 =$ ·002,534
109·2	·122	·190	·180	·147	– ·025	$S_2^2 =$ 0·825,505
112·6	·136	·257	·198	·096	·040	$S_3^2 =$ ·035,347
118·2	·032	·051	·064	·036	– ·004	
121·7	0	0	0	·016	– ·016	$g =$ ·8846
129·8	0	0	0	·001	– ·001	

$\Sigma\bar{R}_r = {\cdot}494''$ $\Sigma\bar{R} = {\cdot}494''$ $\Sigma(\bar{R}_r - \bar{R}) = 0''$

GROUP 16, – – + *A* WINDS.

$$\bar{R} = 0{\cdot}201'' \cdot 10^{-\frac{25}{100,000}(P-85)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
94·2	·188	·152	·146	·191	– ·003	$S_1^2 =$ ·073,552
102·0	·136	·089	·086	·170	– ·034	$S_2^2 =$ 2·011,295
105·6	·274	·241	·204	·157	·117	$S_3^2 =$ ·111,962
108·6	·110	·149	·114	·146	– ·036	
110·6	·110	·132	·154	·138	– ·028	$g =$ ·6175
112·4	·220	·271	·201	·130	·090	
114·2	·092	·138	·114	·123	– ·031	
115·6	·050	·034	·044	·117	– ·067	
116·2	·064	·077	·066	·115	– ·051	
117·6	·054	·119	·085	·109	– ·055	
119·0	·084	·050	·068	·103	– ·019	
119·6	·140	·128	·109	·101	·039	
120·8	·174	·106	·173	·096	·078	
121·0	·174	·106	·184	·095	·079	
122·0	·046	·046	·063	·091	– ·045	
122·6	·066	·064	·066	·089	– ·023	
123·4	·132	·202	·173	·086	·046	
124·6	·084	·204	·184	·081	·003	
126·4	·030	·048	·060	·075	– ·045	
128·2	·016	·037	·036	·069	– ·053	
129·4	·044	·053	·058	·065	– ·021	
130·8	·020	·027	·037	·060	– ·040	
133·0	·018	·029	·036	·053	– ·035	
135·8	·130	·152	·182	·046	·084	
138·6	·032	·038	·047	·038	– ·006	
143·6	·086	·138	·172	·028	·058	

$\Sigma\bar{R}_r = 2{\cdot}574''$ $\Sigma\bar{R} = 2{\cdot}572''$ $\Sigma(\bar{R}_r - \bar{R}) = {\cdot}002''$

GROUP 16, – – + *B* WINDS.

$$\bar{R} = 0{\cdot}226'' \cdot 10^{-\frac{94}{100,000}(P-95)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
102·6	·220	·212	·237	·199	·021	$S_1^2 =$ ·024,955
111·8	·026	·042	·052	·123	– ·097	$S_2^2 =$ 1·037,352
115·4	·120	·184	·230	·092	·028	$S_3^2 =$ ·062,447
119·2	·168	·241	·301	·064	·104	
123·4	·002	·003	·004	·039	– ·037	$g =$ ·6834
125·2	·002	·003	·004	·031	– ·029	
127·8	0	0	0	·022	– ·022	
130·6	·038	·060	·063	·015	·023	
132·2	·004	·009	·009	·011	– ·007	
134·6	·006	·007	·008	·008	– ·002	
136·0	·008	·010	·012	·006	·002	
141·6	·017	·020	·024	·002	·015	

$\Sigma\bar{R}_r = {\cdot}611''$ $\Sigma\bar{R} = {\cdot}612''$ $\Sigma(\bar{R}_r - \bar{R}) = -{\cdot}001''$

GROUP 17, – – 0 *A* WINDS.

$$\bar{R} = 0{\cdot}562'' \cdot 10^{-\frac{34}{100,000}(P-70)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
86·0	·360	·256	·268	·460	– ·100	$S_1^2 = \cdot085{,}864$
95·2	·396	·367	·260	·342	·054	$S_2^2 = 3\cdot079{,}390$
98·8	·480	·416	·332	·294	·186	$S_3^2 = \cdot347{,}702$
101·8	·242	·143	·161	·255	– ·013	
104·0	·158	·177	·131	·227	– ·069	$g = \cdot6660$
106·2	·134	·093	·088	·201	– ·067	
108·4	·284	·380	·296	·177	·107	
110·2	·182	·297	·211	·159	·023	
112·2	·186	·199	·197	·139	·047	
114·0	·198	·238	·262	·123	·075	
115·8	·090	·108	·099	·109	– ·019	
116·8	·074	·068	·090	·101	– ·027	
117·2	·056	·058	·080	·098	– ·042	
118·4	·094	·256	·174	·090	·004	
119·8	·040	·137	·132	·081	– ·041	
121·2	·044	·046	·046	·072	– ·028	
123·6	·004	·011	·009	·059	– ·055	
128·0	·020	·032	·040	·040	– ·020	
134·8	·002	·003	·004	·021	– ·019	

$\Sigma\bar{R}_r = 3{\cdot}044''$ $\Sigma\bar{R} = 3{\cdot}048''$ $\Sigma(\bar{R}_r - \bar{R}) = -\cdot004''$

GROUP 17, – – 0 *B* WINDS.

$$\bar{R} = 0{\cdot}615'' \cdot 10^{-\frac{26}{10,000}(P-90)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
100·0	·326	·195	·254	·338	– ·012	$S_1^2 = \cdot007{,}673$
106·6	·050	·069	·081	·118	– ·068	$S_2^2 = \cdot493{,}526$
110·0	·070	·105	·088	·056	·014	$S_3^2 = \cdot082{,}307$
114·0	·042	·114	·083	·020	·022	
117·8	·002	·003	·004	·006	– ·004	$g = \cdot7468$
125·0	0	0	0	0	0	
130·4	0	0	0	0	0	
134·0	·047	·078	·104	0	·047	

$\Sigma\bar{R}_r = \cdot537''$ $\Sigma\bar{R} = \cdot538''$ $\Sigma(\bar{R}_r - \bar{R}) = -\cdot001''$

GROUP 18, – – – *A* WINDS.

$$\tilde{R} = 0{\cdot}784'' \cdot 10^{-\frac{24}{100,000}(P-60)^2}$$

$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
67·2	·598	·306	·344	·762	– ·164	$S_1^2 =$ ·618,998
80·0	·958	·250	·276	·629	·329	$S_2^2 =$ 10·624,160
86·0	·366	·306	·366	·540	– ·174	$S_3^2 =$ 1·174,775
88·2	·262	·287	·201	·505	– ·243	
90·4	·384	·256	·191	·470	– ·086	$g =$ ·5172
93·4	·468	·318	·321	·423	·045	
96·6	·748	·752	·829	·374	·374	
99·4	·682	·665	·780	·332	·350	
102·2	·270	·137	·131	·293	– ·023	
103·6	·166	·226	·178	·274	– ·108	
104·6	·048	·043	·046	·261	– ·213	
106·8	·372	·326	·395	·234	·138	
111·0	·284	·336	·319	·186	·098	
112·6	·032	·110	·082	·170	– ·138	
116·0	·046	·058	·073	·139	– ·093	
122·0	0	0	0	·094	– ·094	

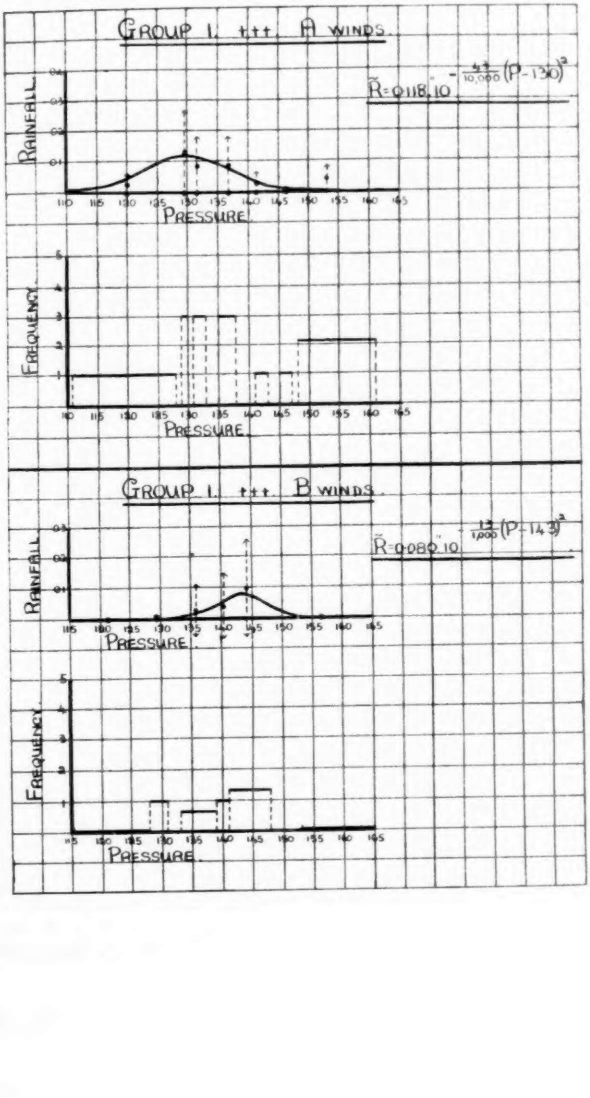
$\Sigma\bar{R}_r = 5{\cdot}684''$ $\qquad$ $\Sigma\bar{R} = 5{\cdot}686''$ $\quad \Sigma(\bar{R}_r - \bar{R}) = -{\cdot}002''$

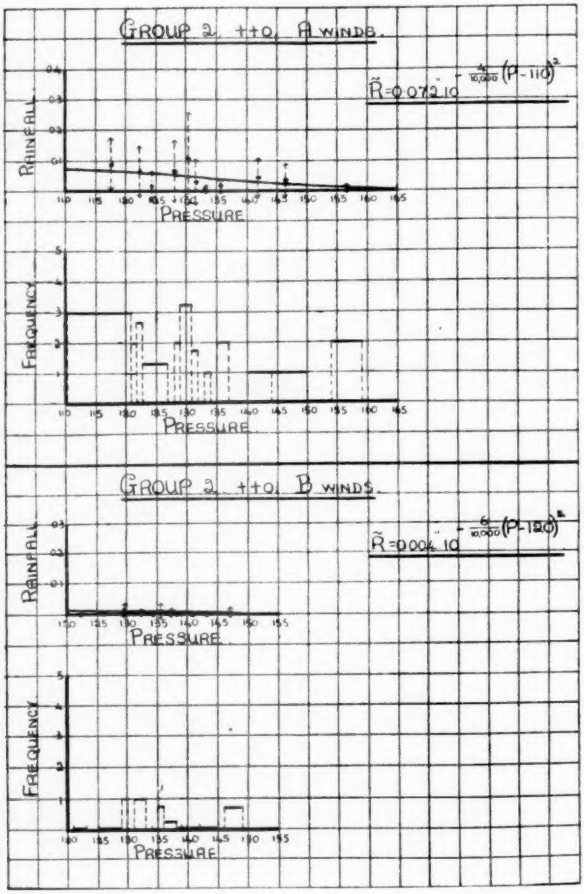
GROUP 18, – – – *B* WINDS.

$$\tilde{R} = 1{\cdot}218'' \cdot 10^{-\frac{6}{10,000}(P-60)^2}$$

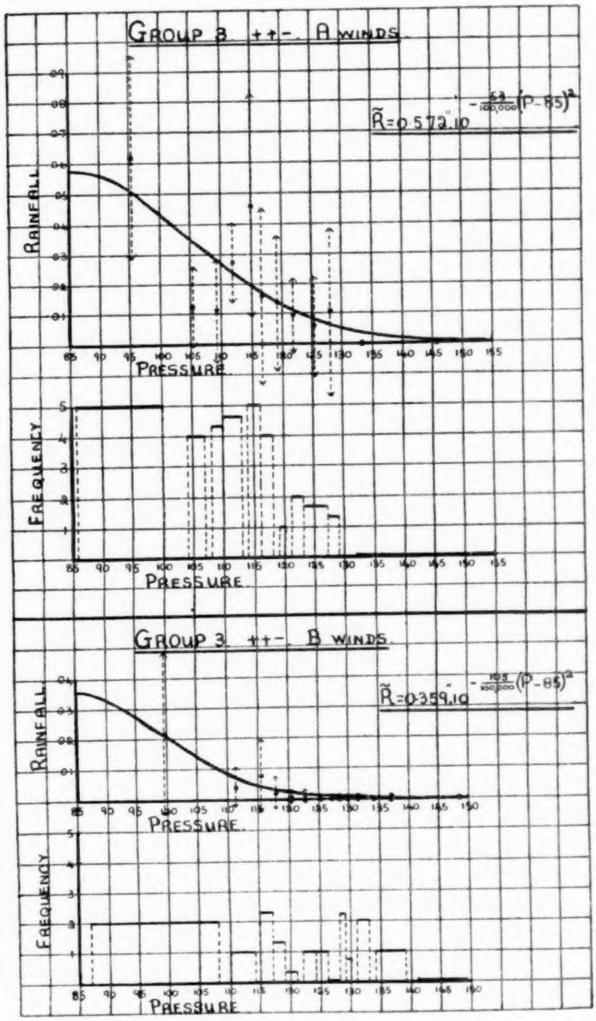
$\bar{P}_r$.	$\bar{R}_r$.	d_r.	σ_r.	$\bar{R}$.	$\bar{R}_r - \bar{R}$.	Variances.
80·8	·632	·472	·493	·670	– ·038	$S_1^2 =$ ·016,529
100·4	·068	·147	·098	·128	– ·060	$S_2^2 =$ 1·525,825
109·0	·002	·003	·004	·044	– ·042	$S_3^2 =$ ·267,877
115·4	·082	·131	·164	·018	·064	
123·6	·080	·128	·160	·005	·075	$g =$ ·7918

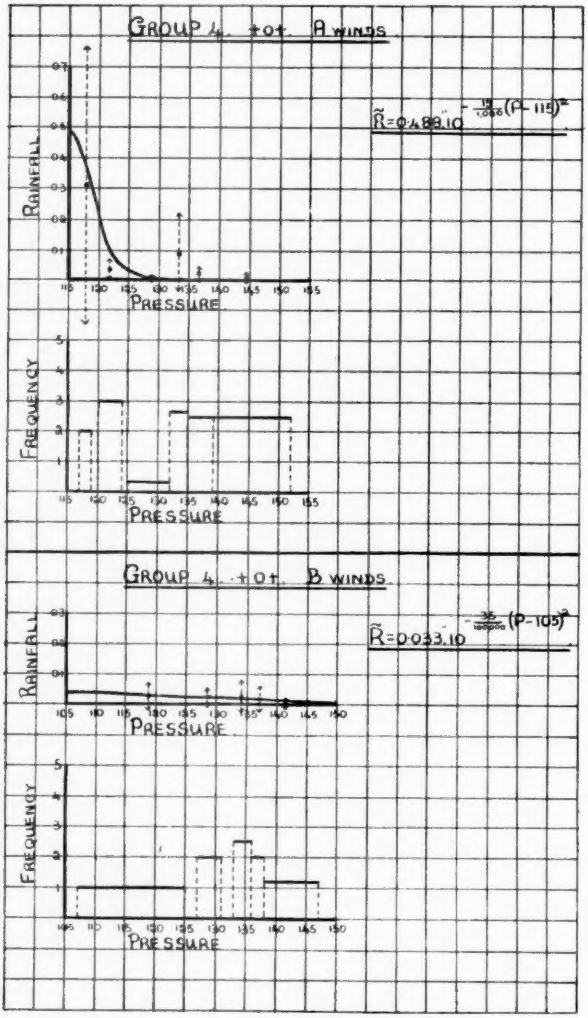
$\Sigma\bar{R}_r = {\cdot}864''$ $\qquad$ $\Sigma\bar{R} = {\cdot}865''$ $\quad \Sigma(\bar{R}_r - \bar{R}) = -{\cdot}001''$

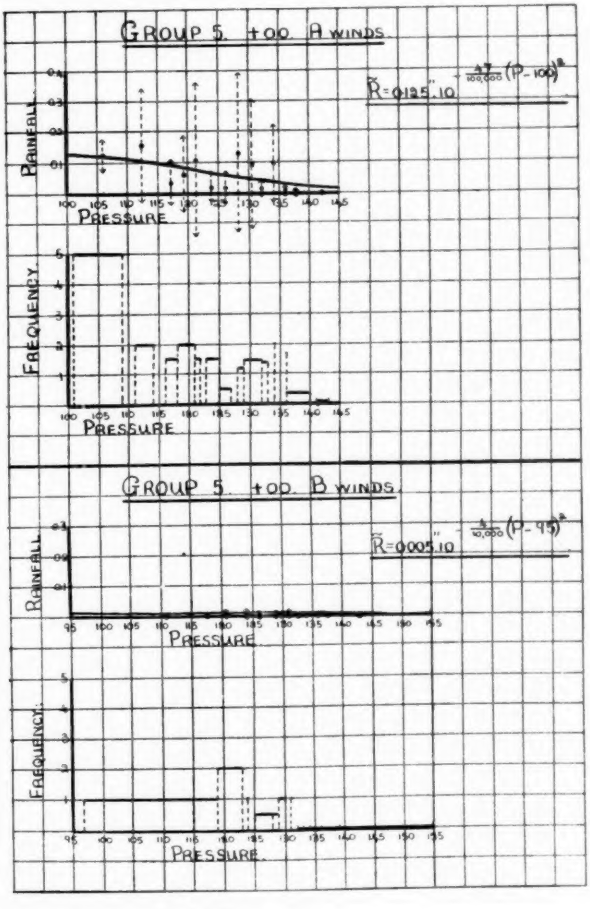

GROUP I. ttt. A WINDS.
RAINFALL.
PRESSURE.
FREQUENCY.
PRESSURE.
GROUP I. ttt. B WINDS.
RAINFALL.
PRESSURE.
FREQUENCY.
PRESSURE.

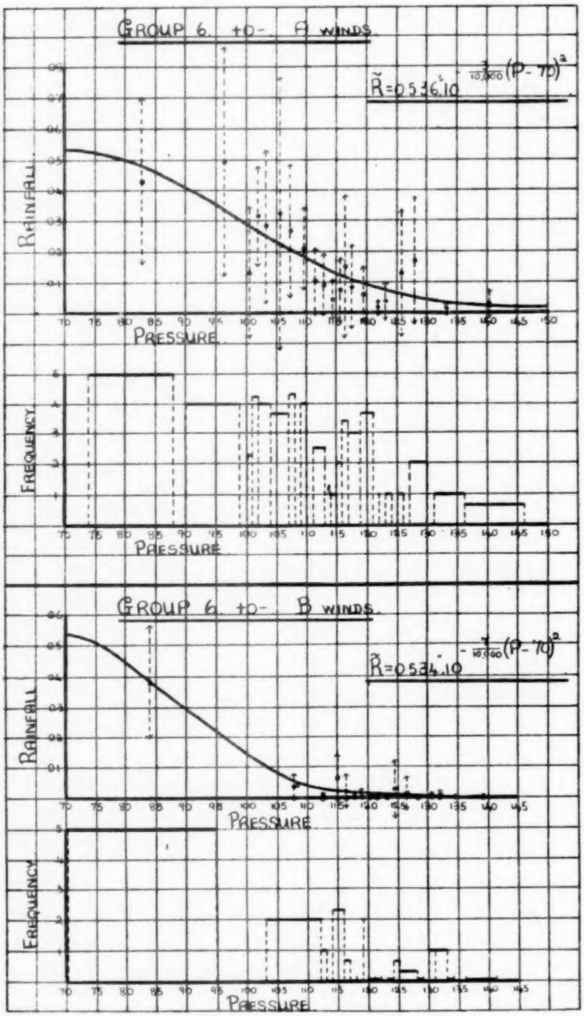


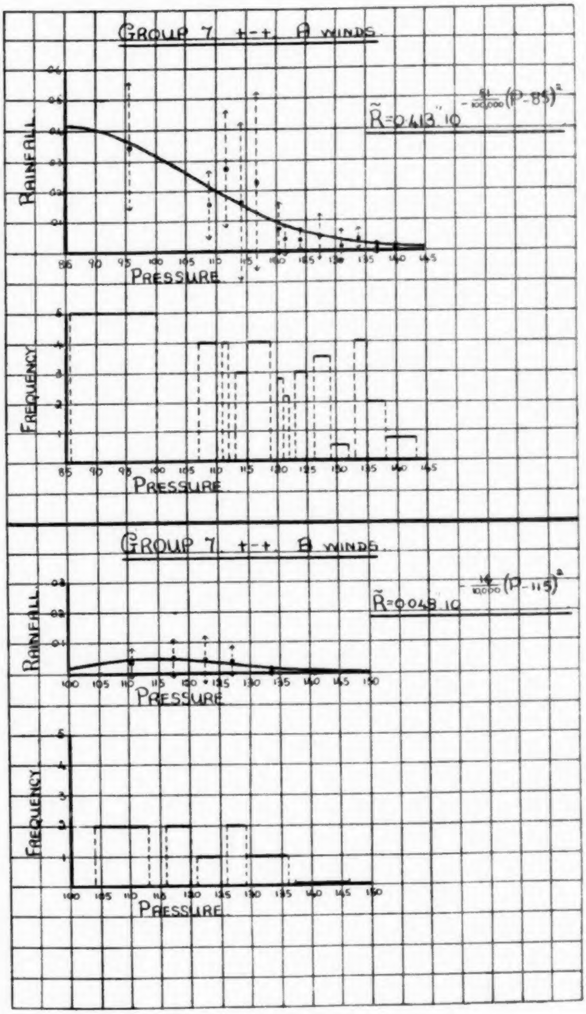
GROUP 2. ++0. A WINDS.
$\tilde{R}=0{\cdot}072 \cdot 10^{-\frac{4}{10,000}(P-110)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 2. ++01 B WINDS.
$\tilde{R}=0{\cdot}004 \cdot 10^{-\frac{6}{10,000}(P-120)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

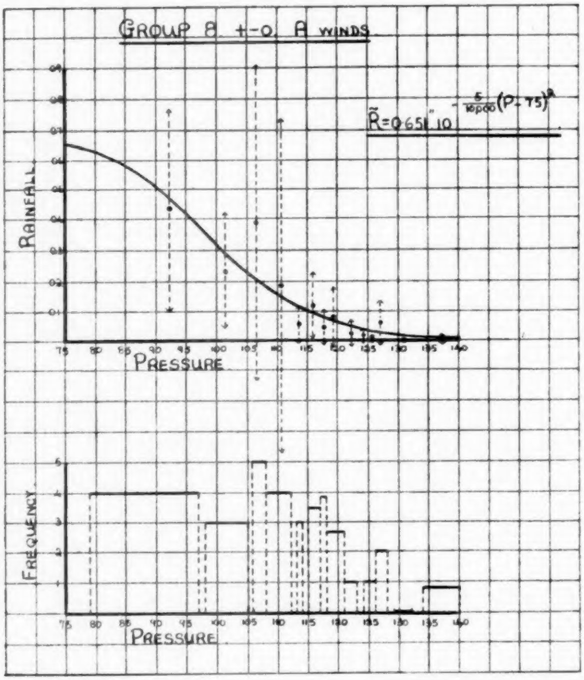

GROUP 3. ++-. A WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 3. ++-. B WINDS.
RAINFALL
PRESSURE.
FREQUENCY
PRESSURE

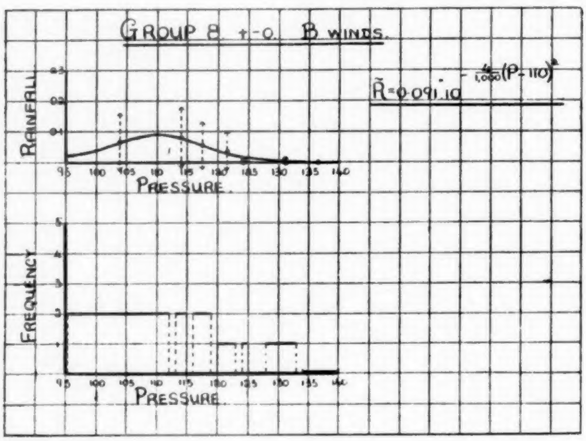

GROUP 4. +0+. A WINDS.
$\tilde{R}=0.488.10^{-\frac{19}{1,000}(P-115)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 4. +0+. B WINDS.
$\tilde{R}=0.033.10^{-\frac{35}{100,000}(P-105)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

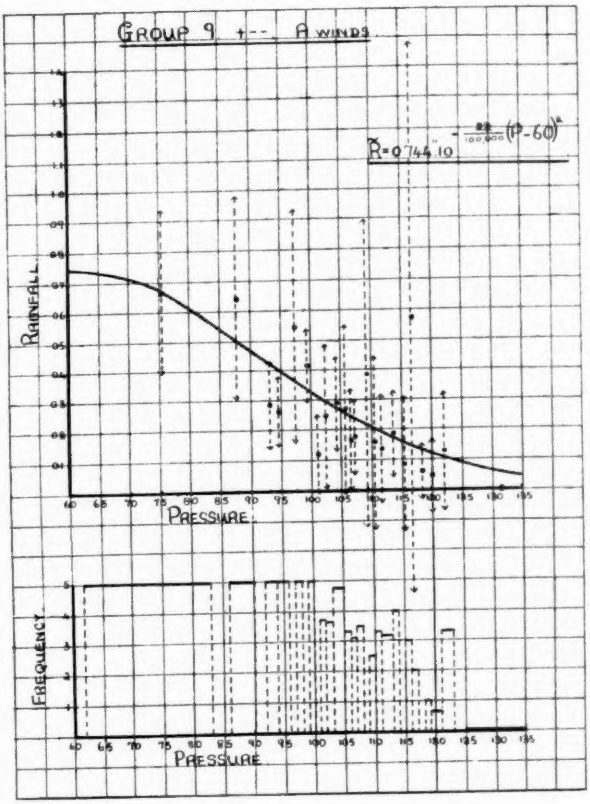

GROUP 5. +00. A WINDS.
RAINFALL.
PRESSURE
FREQUENCY.
PRESSURE
GROUP 5. +00. B WINDS.
RAINFALL
PRESSURE
FREQUENCY.
PRESSURE.

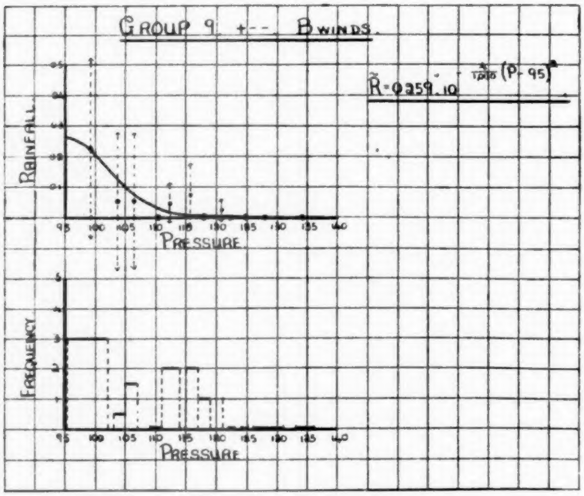

GROUP 6. to- A WINDS
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 6. to- B WINDS
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

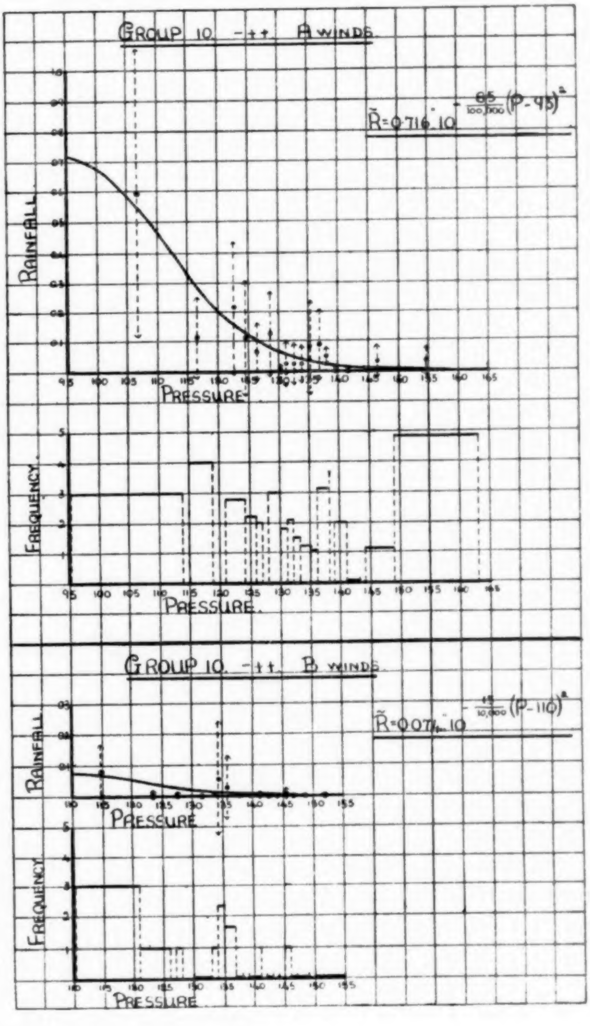

GROUP 7. +-+. B WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 7. +-+. B WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

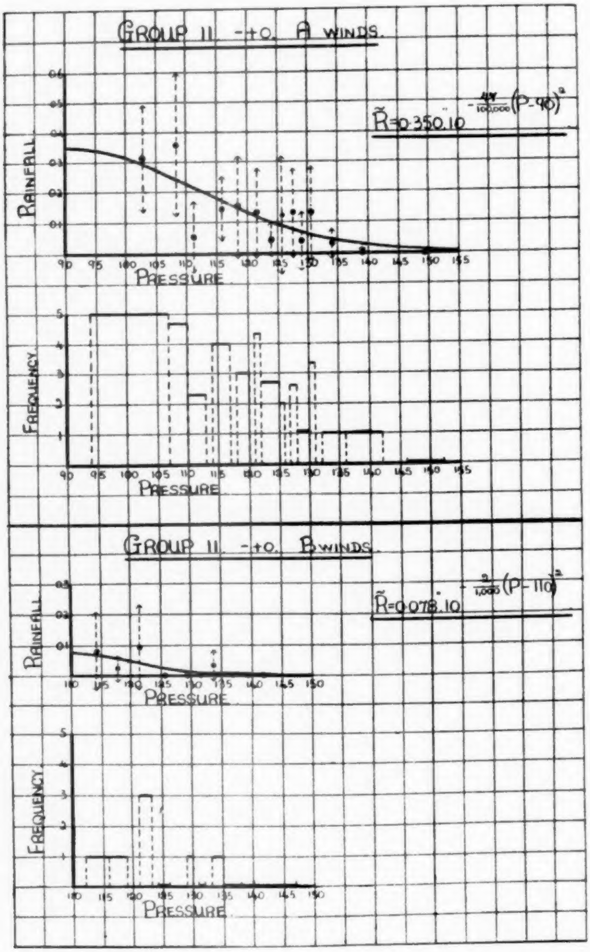

GROUP 8 +-0. A WINDS
$\tilde{R}=0{\cdot}651'' \cdot 10^{-\frac{5}{10,000}(P-75)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE


GROUP 8 +-0. B WINDS.
$\tilde{R}=0{\cdot}091'' \cdot 10^{-\frac{4}{1,000}(P-110)^2}$
RAINFALL
PRESSURE.
FREQUENCY
PRESSURE.

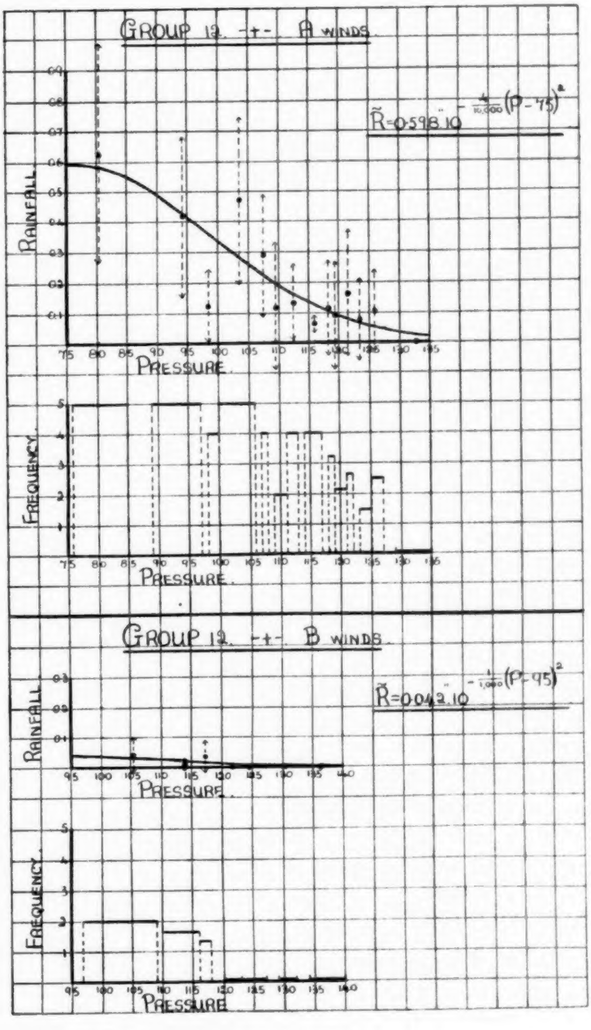

GROUP 9 +--. A WINDS.
RAINFALL.
PRESSURE.
FREQUENCY.
PRESSURE.

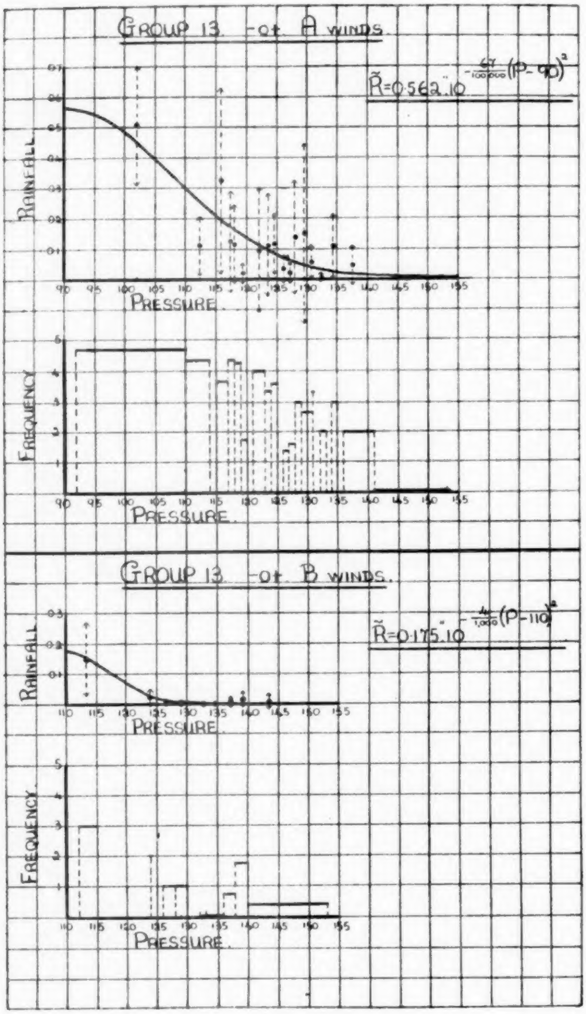

GROUP 9 +-- B WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

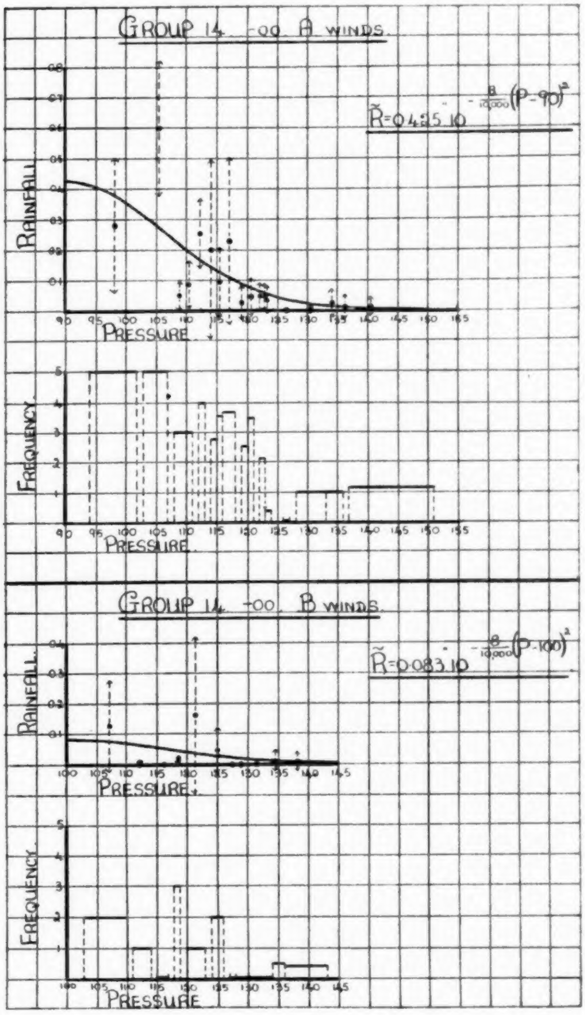

GROUP 10. -++ A WINDS
$\tilde{R}=0.716 \cdot 10^{-\frac{65}{100,000}(P-95)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 10. -++ B WINDS
$\tilde{R}=0.07 \cdot 10^{-\frac{15}{10,000}(P-110)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

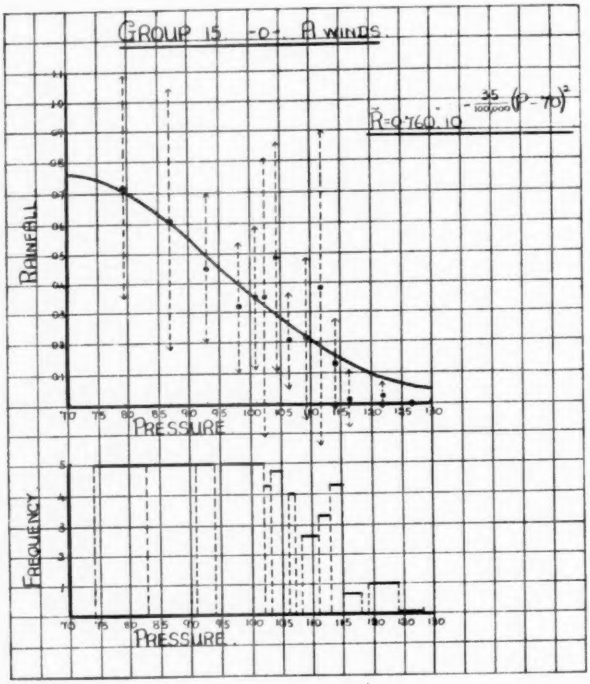


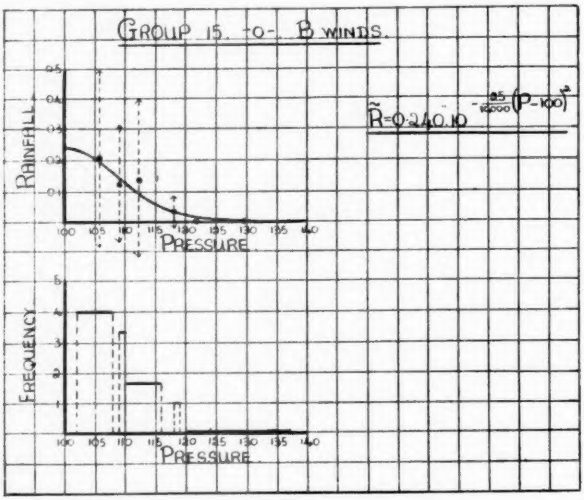
GROUP II. -+O. A WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP II. -+O. B WINDS.
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

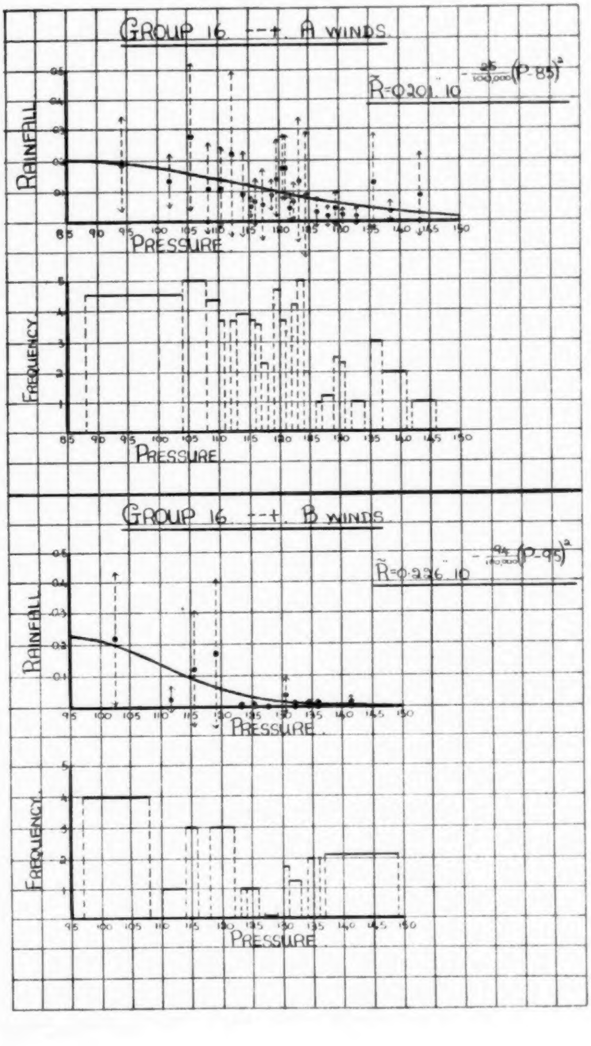

GROUP 12. -+- A WINDS.
$\tilde{R}=0.598.10^{-\frac{1}{10,000}(P-75)^2}$
RAINFALL
PRESSURE.
FREQUENCY.
PRESSURE.
GROUP 12. -+- B WINDS.
$\tilde{R}=0.042.10^{-\frac{1}{1,000}(P-95)^2}$
RAINFALL
PRESSURE.
FREQUENCY.
PRESSURE

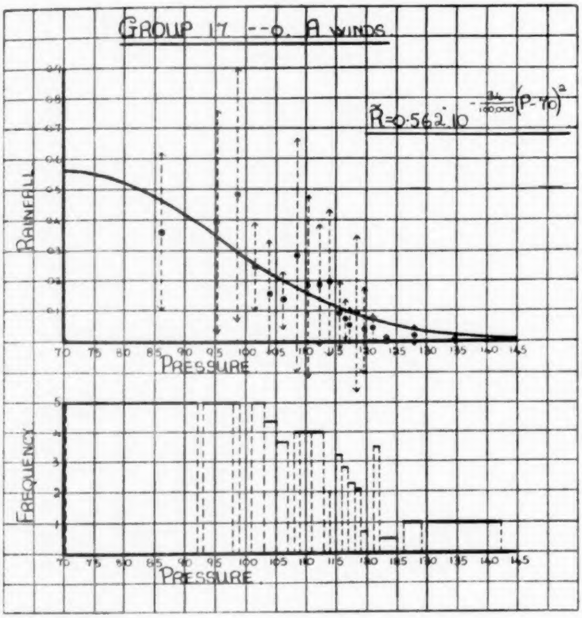

GROUP 13. -0+. A WINDS.
RAINFALL
PRESSURE.
FREQUENCY
PRESSURE.
GROUP 13. -0+. B WINDS.
RAINFALL
PRESSURE.
FREQUENCY.
PRESSURE.

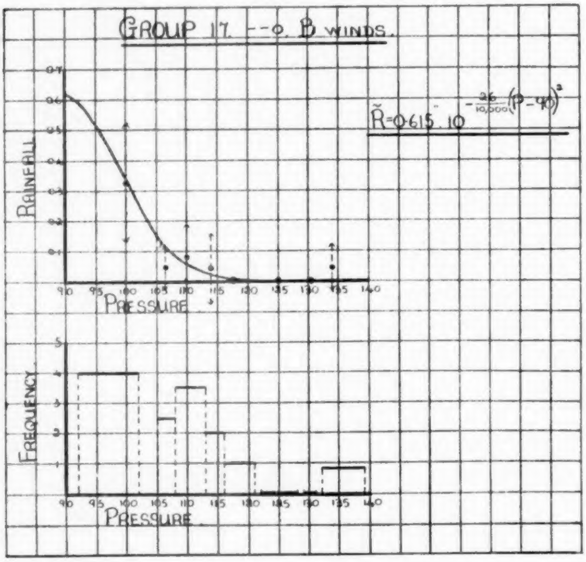

GROUP 14 -00 A WINDS.
$\tilde{R}=0.425.10^{-\frac{8}{10,000}(P-90)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 14 -00 B WINDS.
$\tilde{R}=0.083.10^{-\frac{8}{10,000}(P-100)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

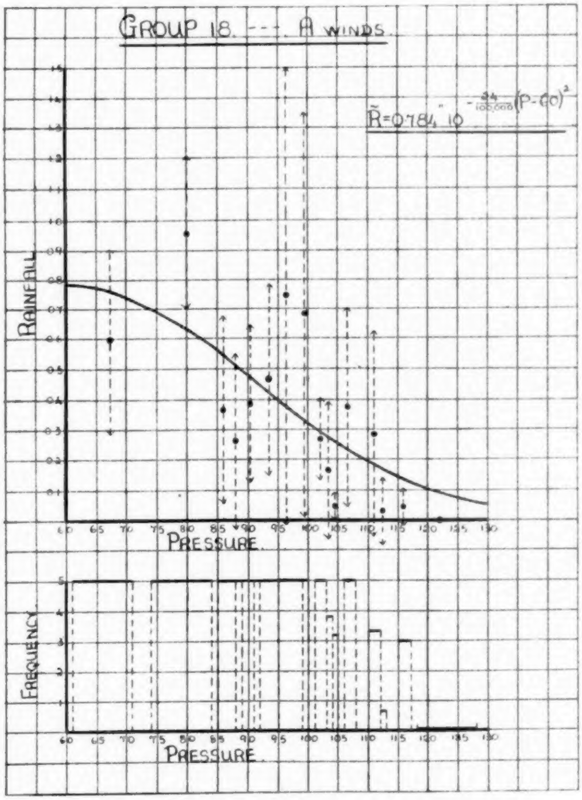

GROUP 15. -0-. A WINDS.
R̃=0·760.10^{-35/100,000 (P-70)²}
RAINFALL
PRESSURE
FREQUENCY
PRESSURE

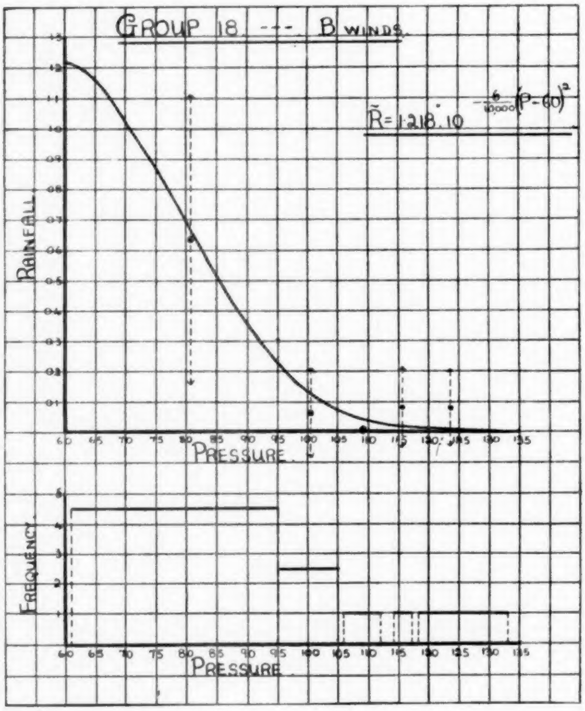

GROUP 15. -0-. B WINDS.
R̃=0·240.10^{-25/10,000 (P-100)²}
RAINFALL
PRESSURE
FREQUENCY
PRESSURE


GROUP 16. --+. A WINDS
RAINFALL
PRESSURE
FREQUENCY
PRESSURE
GROUP 16. --+. B WINDS
RAINFALL
PRESSURE
FREQUENCY
PRESSURE


GROUP 17 --o. A WINDS.
$\tilde{R}=0.562\,10^{-\frac{34}{100,000}(P-70)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE.


GROUP 17 --o. B WINDS.
$\tilde{R}=0.615\,10^{-\frac{26}{10,000}(P-90)^2}$
RAINFALL
PRESSURE
FREQUENCY
PRESSURE.


GROUP 18. --- A WINDS.
$\tilde{R} = 0{\cdot}784'' \; 10^{-\frac{24}{100,000}(P-60)^2}$
RAINFALL
PRESSURE.
FREQUENCY
PRESSURE.


GROUP 18 --- B WINDS.
$\bar{R} = 1{\cdot}218 \cdot 10^{-\frac{6}{10{,}000}(P-60)^2}$
RAINFALL.
PRESSURE.
FREQUENCY.
PRESSURE.

A STUDY OF THE ASPIRATION PSYCHROMETER.*

By Athelstan F. Spilhaus.

(Department of Defence, Pretoria, Union of South Africa, December 1935.)

(Communicated by A. Brown.)

(With ten Text-figures.)

(Read March 18, 1936.)

Synopsis.

1. The time allowed for the aspiration psychrometer to come to equilibrium is usually governed by empirical rules. The Prussian Meteorological Institute gives three minutes as the minimum interval between the beginning of ventilation and the first reading. In the following investigation the rate at which the wet bulb assumes its equilibrium condition is found to be characterised, to a close approximation, by the factor ξ in the transient expression for a first order process

$$\log \frac{T_f' - T_i'}{T_f' - T_0'} = \xi t,$$

where T_f' is the final wet bulb temperature.

T_i' is the indicated wet bulb temperature at a time, t, from the start of ventilation.

T_0' is the original wet bulb temperature at the start of ventilation.

ξ depends on the heat capacity of the thermometer, the atmospheric pressure, the ventilation and the range through which the indicated wet bulb temperature passes.

2. The connection between the work on evaporation and psychrometric theory is indicated, and the effect of radiation on the psychrometer is discussed.

3. Robitzsch † has remarked on the difficulty of obtaining accurate observations of the vapour pressure with a sensitive psychrometer, owing

* Published by permission of the Director of Military Operations and Training, South African Permanent Force.

† "Die Beobachtungsmethoden des modernen Meteorologen," Sammlung geophysikalische Schriften, No. 4, p. 57, Borntraeger, Berlin, 1925.

to the short period fluctuations of temperature which occur in the atmosphere. Anyone who has operated such a psychrometer in the free air is aware of the fluctuation of the readings which lead in general to a fictitious fluctuation in the value of the observed vapour pressure. It will be shown that by suitably arranging a ventilation for the dry bulb, in general, different from that of the wet bulb, a constant vapour pressure estimation can be obtained in spite of wide fluctuations of temperature.

The Psychrometer Transient.

In the simplest form of the theory of the psychrometer the heat given up by the air in unit time may be measured by the mass of air, m_1, which would be cooled from T to T′, and this amount of heat is equal to the heat necessary to evaporate sufficient water to saturate a mass of air, m_2, at the temperature T′.

Thus $m_1 C_p(T - T') = \frac{e'_{T'} - e}{P} r m_2 L_{T'}$, where

T = air temperature,
T' = wet bulb temperature,
$e'_{T'}$ = saturation vapour pressure at T′,
e = actual vapour pressure,
$L_{T'}$ = latent heat of vaporisation at T′,
C_p = specific heat of air at constant pressure,
P = barometric pressure,
r = ratio of the molecular weight of water vapour to the molecular weight of air,

and m_1 and m_2 have the meanings attributed to them above and are both functions of ventilation.

Suppose now that the wet bulb thermometer is in the process of coming to equilibrium and T_i' is the indicated wet bulb temperature. The thermometer with wick and water has a heat capacity $= C_1$.

Then, in an interval dt of the cooling process the loss of heat from the bulb $= C_1 dT_i'$, and the loss of heat from the air in being cooled from T to $T_i' = m_1 C_p(T - T_i')dt$.

The sum of these two losses equals the heat used for evaporation, *i.e.*

$$C_1 dT_i' + m_1 C_p(T - T_i')dt = \frac{e'_{T_i'} - e}{P} r m_2 L_{T_i'} dt,$$

neglecting the small variation of $L_{T_i'}$ with T_i', putting $L_{T_i'} = L$ = constant, and assuming that, over the small range, $e'_{T_i'}$ may be represented as a linear function of T_i', putting $e'_{T_i'} = a + \beta T_i'$, we obtain, on rearrangement,

$$\frac{dT_i'}{dt} - \frac{m_2 rL}{PC_1}\left(\frac{m_1 C_p P}{m_2 rL} + \beta\right)T_i' + \frac{m_2 rL}{PC_1}\left(\frac{m_1 C_p P}{m_2 rL}T - a + e\right) = 0.$$

Now $\frac{m_1 C_p}{m_2 rL}P = A$, a psychrometric constant for constant ventilation and constant pressure.

If we put

$$\frac{m_2 rL}{PC_1}(A + \beta) = \xi,$$

and

$$\frac{m_2 rL}{PC_1}(AT - a + e) = \eta.$$

Then

$$\frac{dT_i'}{\xi T_i' - \eta} = dt.$$

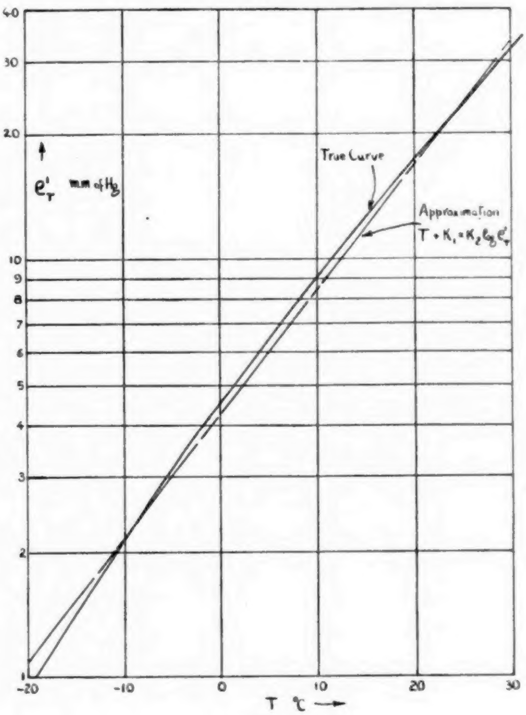


Fig. 1.

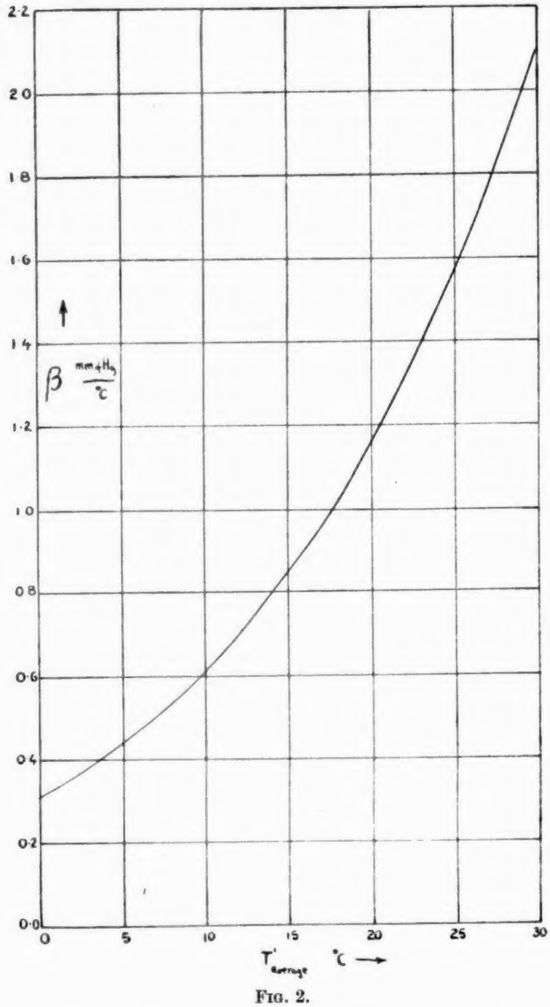


FIG. 2.

Integrating and inserting the boundary condition $t=0$, $T_i'=T_0'$

$$\log\left(\frac{T_i'-\frac{\eta}{\xi}}{T_0'-\frac{\eta}{\xi}}\right)=\xi t,$$

but when

$$t = \infty, \qquad T_i' = T_f' \qquad \therefore \frac{\eta}{\xi} = T_f'$$

and

$$\log \left(\frac{T_i' - T_f'}{T_0' - T_f'} \right) = \xi t.$$

From transient tests ξ can be found for various ventilations, and the psychrometric constant A can be found in the usual manner for various ventilations.

So that, from

$$\xi = \frac{m_2 r L}{PC_1}(A + \beta)^*$$

and

$$A = \frac{m_1 C_p}{m_2 r L} P$$

the variation of $\frac{m_2}{C_1}$ and $\frac{m_1}{C_1}$ with ventilation can be found severally.

In fig. 3 the variation with ventilation of the psychrometric constant for the experimental dry and wet bulb arrangement is shown. Fig. 4 gives, for various ventilations, the values of $\frac{m_2}{C_1}$ obtained from the transient tests and the curve of $\frac{m_1}{C_1}$ computed from the smoothed values of A and $\frac{m_2}{C_1}$.

On the same diagram are plotted curves of ϵ and $\frac{m_3}{C}$ obtained by an independent series of transient tests on the thermometer dry and without the wick. In an exactly analogous fashion to the method adopted for the wet bulb, m_3 represents the mass of air raised from T to T_i in unit time, and C is the heat capacity of the thermometer bulb alone. ϵ is the reciprocal of what is commonly known as the lag coefficient and $\epsilon = \frac{m_3 C_p}{C}$.

---

* β is given by the average slope $\frac{de'_{T'av}}{dT'_{av}}$ between the values T_0' and Tf'.

Now to a close approximation over the normal range $T' + K_1 = K_2 \log e'_{T'}$ (*cf.* fig. 1) and

$$\frac{d(\log e'_{T'})}{dT'} = \frac{1}{K_2}. \qquad \therefore \frac{de'_{T'}}{dT'} = \frac{e'_{T'}}{K_2} = \beta$$

for $e'_{T'}$ in mm. of mercury and T' in ° C., $K_2 = 15$. Fig. 2 shows the variations of β with T' (average) on this basis.

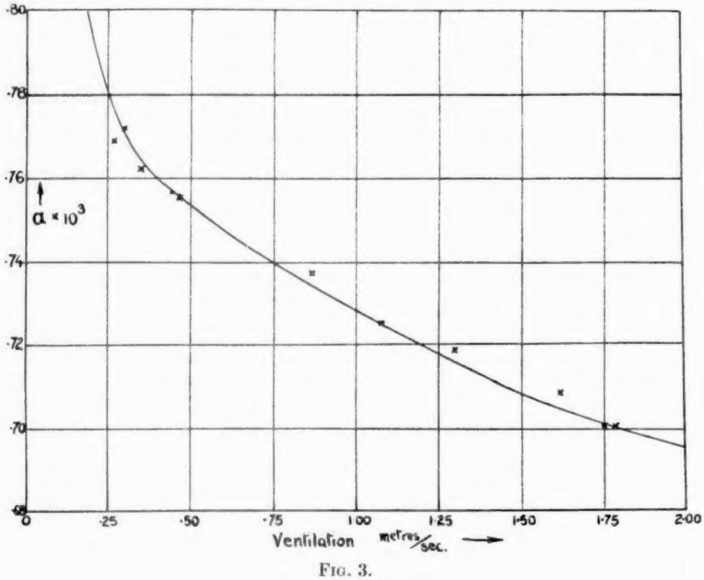

·80
·78
·76
·74
·72
·70
·68
$a \times 10^3$
0
·25
·50
·75
1·00
1·25
1·50
1·75
2·00
Ventilation metres/sec.

FIG. 3.

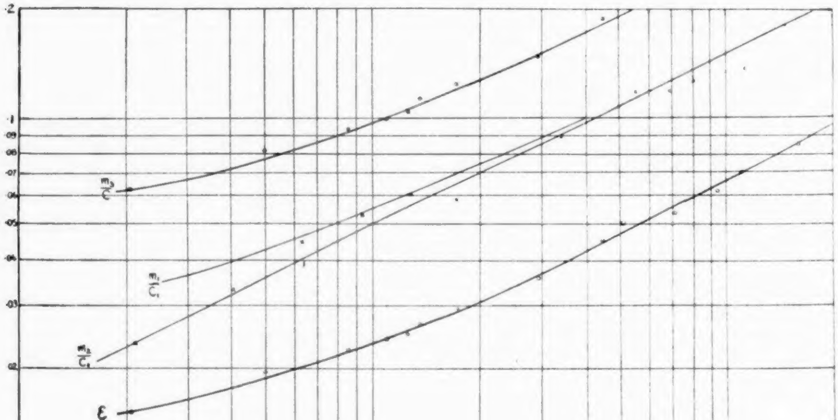

Ventilation v m/s
ε

FIG. 4.

In fig. 4 the curves for $\frac{m_3}{C}$ and $\frac{m_1}{C_1}$ appear to run almost parallel, which means that

$$\frac{m_3}{C} \Big/ \frac{m_1}{C_1} = N = \text{constant}.$$

It is reasonable to infer from this that the influence of the increased eddy conductivity, due to the wick around the wet bulb, is negligible, and that

$$m_3 = m_1$$
$$\therefore \quad \frac{C_1}{C} = N.$$

From the figure, N is equal to about 1·75, which indicates that the equivalent heat capacity of the thermometer bulb is increased about 75 per cent. by the wick and water.

The Nature of the Variation of the Psychrometric Constant with Ventilation.

At high velocities it is evident that m_1 becomes equal to m_2 (*i.e.* a becomes constant with ventilation). This corresponds to Humphrey's * treatment, where, excluding all radiation effects, he places $m_1 = m_2$. It might be expected, therefore, following Humphreys, that the divergence of m_1 from m_2 at low ventilations is due to radiation influences alone. If this is the case then m_1 may be written

$$m_1 = m_2 + K,$$

where K depends solely on the physical constants of the wet bulb and on T and T′.

In view of the fact that T and T′ were very nearly constant through these tests, the relation

$$\frac{m_1}{C_1} = \frac{m_2}{C_1} + \frac{K}{C_1}$$

should hold for the curves in fig. 4. Examination reveals that this is substantially true within the limits of experimental accuracy.

Now

$$a = \frac{m_1}{m_2} \frac{C_p}{rL}$$

and

$$a_\infty = \frac{C_p}{rL} \text{ (for high ventilations)},$$

* Physics of the Air, p. 14, McGraw-Hill, New York.

so that

$$\frac{a - a_\infty}{a_\infty} = \frac{m_1}{m_2} - 1 = \frac{K}{m_2}$$

and from the figure $m_2 = K_3 v^n$ (where $n = \frac{1}{2}$ approx.)
thus

$$\frac{a - a_\infty}{a_\infty} = K_4 v^{-n}.$$

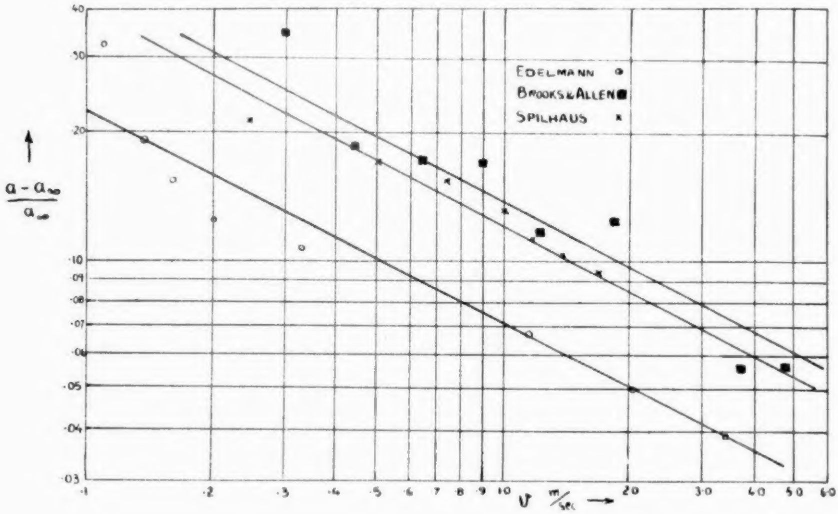


Fig. 5.

Fig. 5 shows the values of $\frac{a - a_\infty}{a_\infty}$ for various ventilations from the tests of Edelmann,* Brooks and Allen,† and the present author. In every case a_∞ was taken to be ·00064, and the relationship $\frac{a - a_\infty}{a_\infty}$ is fairly well shown.

The Influence of the Size of the Wet Bulb.

Tests were carried out on three thermometers having spherical bulbs of different diameters (6·3 mm., 8·5 mm., and 13·0 mm.) to obtain the

* "Psychrometrische Studien und Beiträge," Meteorol. Zeitschr., 1896, vol. xiii, p. 325.

† "Some Improvements in Psychrometry," J. Wash. Acad. Sci., 1933, vol. xxiii, No. 3.

variation of $\frac{m_2}{C_1}$ and $\frac{m_3}{C}$ with the bulb diameter. The results of these tests plotted in fig. 6 show that

$$\frac{m_2}{c_1} = K_5 \frac{v^n}{d^{\frac{3}{2}}}$$

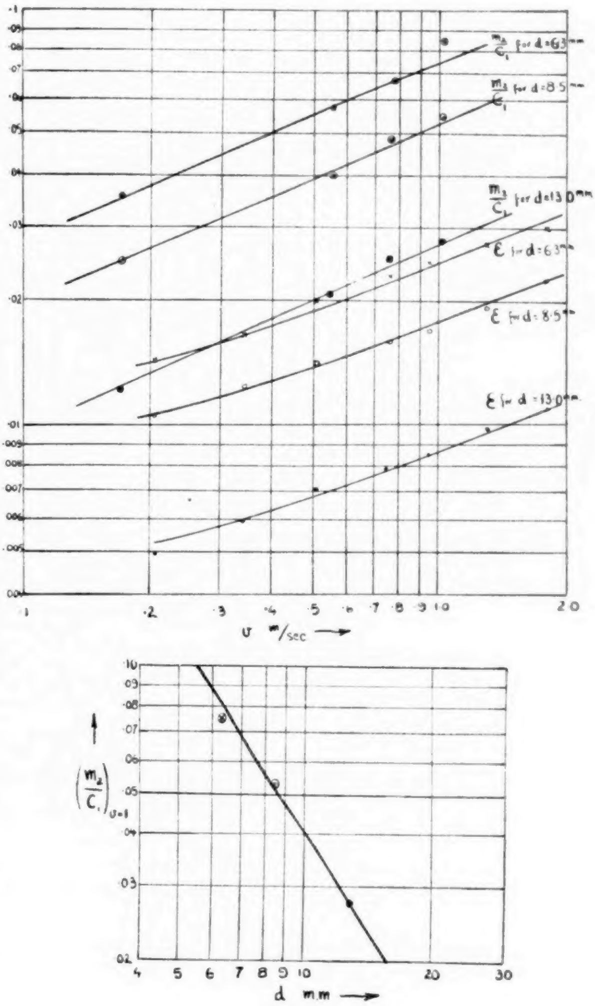


FIG. 6.

Now C_1 varies very nearly with the volume of the bulb, *i.e.* with d^3.

$$\therefore \; m_2 = K_6 v^n d^{\frac{3}{2}}.$$

Similarly

$$m_3 \propto d^{\frac{3}{2}}.$$

It is interesting to note that this experimental relation obtained for m_2 gives an expression for the total evaporation from the wet bulb of

$$m_2 r \frac{e'_{T'} - e}{P} \propto \frac{e'_{T'} - e}{P} v^n d^{\frac{3}{2}},$$

where η is nearly $= \frac{1}{2}$.

This is in good agreement with the expression given by Jeffreys,* where he finds for areas of the same shape that the total evaporation into a steady wind is

$$3{\cdot}95 \rho V_0 (D v d^3)^{\frac{1}{2}}$$

where V_0 is the difference of the humidity mixing ratio at the water surface where the air is saturated and at a great distance. Thus for constant eddy diffusivity, D, and constant density, ρ, Jeffreys' total evaporation is $\propto \left(\frac{e'_{T'} - e}{P} \right) v^{\frac{1}{2}} d^{\frac{3}{2}}$.

The agreement is the more surprising when it is considered that the wet bulb is entirely outside the limitations of Jeffreys' theoretical results.

The Psychrometric Constant as a Function of the size of the Wet Bulb.

From page 192 above the psychrometric constant may be written

$$\frac{a}{a_\infty} = 1 + \frac{K}{m_2}.$$

K may be designated as the mass of air cooled from T to T′ by radiation to the wet bulb in unit time. The total energy received by the wet bulb in unit time is proportional to $d^2(T^4 - T'^4)$, and therefore

$$K \propto d^2 (T^2 + T'^2)(T + T').$$

$$\therefore \; \frac{a - a_\infty}{a_\infty} = \frac{K}{m_2} \propto \sqrt{\frac{d}{v}} (T^2 + T'^2)(T + T').$$

The measurements of a for the three different sized thermometers for different ventilations showed a considerable amount of scattering, the thermometers not being really sensitive enough for the purpose.

* Phil. Mag., 1918, vol. xxxv, p. 270.

In fig. 7 $\dfrac{a - a_\infty}{a_\infty}$ is plotted against $\dfrac{d}{v}$, and although the general trend is in agreement with the relation $\dfrac{a - a_\infty}{a_\infty} \propto \sqrt{\dfrac{d}{v}}$ there is systematic scattering.

This scattering is greatest for higher ventilations (*i.e.* $\dfrac{d}{v}$ small), and

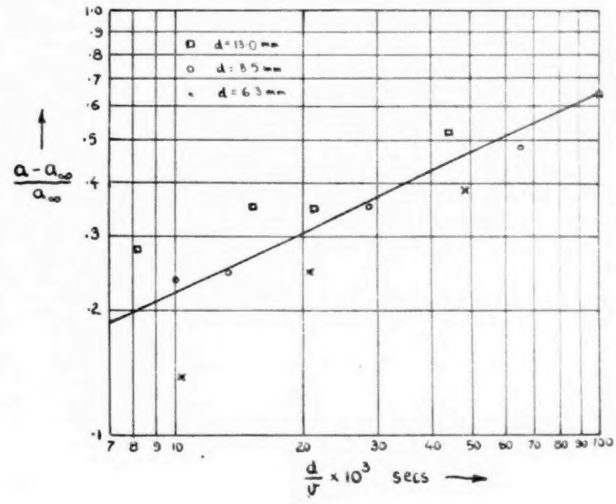


Fig. 7.

it is noteworthy that the determination of the variations in the psychrometric constant become increasingly difficult as the ventilation increases.

It was found impossible to check the relation between $\dfrac{a - a_\infty}{a_\infty}$ and the temperatures; this is understandable when one considers that, over the normal range of operation, $(T^2 + T'^2)(T + T')$ will only vary a very small percentage of its absolute magnitude.

The Measurement of Vapour Pressure in Unsteady Conditions of Temperature.

In general in the free atmosphere the temperature exhibits short-period fluctuations about a mean, and therefore the measurements of vapour pressure obtained from an ordinary sensitive aspiration psychrometer will also show sympathetic fluctuations. There is, however, no ground for

supposing that the short-period fluctuations observed in the vapour pressure are anything but fictitious variations introduced owing to the different response of the dry and wet bulbs to unsteady conditions of temperature. In a correctly designed instrument where the required element is measured by indirect means variations of anything except the required element should not be reflected in the measurement of the latter. It will be shown below that an aspiration psychrometer can be arranged to give the correct constant vapour pressure regardless of temperature fluctuations.

We have, from page 187, the equation for the indicated wet bulb temperature in the unsteady state, *i.e.*

$$\frac{dT_i'}{dt} - \xi T_i' + \frac{m_2 r L}{PC_1}\left(\frac{m_1 C_p P}{m_2 r L} T - a + e\right) = 0,$$

and if we now consider a sinusoidal variation of temperature of amplitude H about a mean value T_0

$$T = T_0 + H \sin \omega t,$$

then

$$\frac{dT_i'}{dt} - \xi T_i' + \frac{m_2 r L}{PC_1}\left(\frac{m_1 C_p P}{m_2 r L} T_0 - a + e\right) + \delta A H \sin \omega t = 0,$$

where

$$\delta = \frac{m_2 r L}{PC_1},$$

as before

$$\eta_{T_0} = \frac{m_2 r L}{PC_1}(AT_0 - a + e)$$

and

$$\frac{\eta_{T_0}}{\xi} = T_0',$$

the true wet bulb temperature corresponding to a vapour pressure, e, at the temperature T_0.

$$\therefore \frac{dT_i'}{dt} - \xi T_i' + \xi T_0' + \delta A H \sin \omega t = 0.$$

Integrating,

$$T_i' = T_0' + \frac{\delta A H}{\sqrt{\xi^2 + \omega^2}} \sin (\omega t + \phi') + M e^{\xi t},$$

where

$$\phi' = \cos^{-1} \frac{\xi}{\sqrt{\xi^2 + \omega^2}}.$$

If the psychrometer is started ($t = 0$) at any condition T_s and T_s' of the dry and wet bulbs respectively, then

$$M = T_s' - T_0' - \frac{\delta A H \omega}{\xi^2 + \omega^2}.$$

Similarly for the dry bulb the equation for the indicated temperature, under the condition of actual temperature $T = T_0 + H \sin \omega t$ is

$$\frac{dT_i}{dt} - \epsilon T_i + \epsilon T_0 + \epsilon H \sin \omega t = 0,$$

where $\epsilon = \frac{m_3 C_p}{C}$, on integration

$$T_i = T_0 + \frac{\epsilon H}{\sqrt{\epsilon^2 + \omega^2}} \sin(\omega t + \phi) + Ne^{\epsilon t},$$

where

$$N = T_s - T_0 - \frac{\epsilon H \omega}{\xi^2 + \omega^2} \quad \text{and} \quad \phi = \cos^{-1} \frac{\epsilon}{\sqrt{\epsilon^2 + \omega^2}}.$$

Combining the steady state portions of these two equations for the wet and dry bulb thermometers (*i.e.* t is sufficiently large so that the transient terms in $e^{\xi t}$ and $e^{\epsilon t}$ disappear), the expression for the psychrometric difference is obtained, and putting $\xi = \epsilon$, *i.e.* $\phi = \phi'$ *

$$T_i - T_i' = T_0 - T_0' + \frac{H(\xi - \delta A)}{\sqrt{\xi^2 + \omega^2}} \sin(\omega t + \phi).$$

Now if Δ is the error introduced by computing the vapour pressure from T_i and T_i' the correct vapour pressure being given by the true mean conditions T_0 and T_0', then from the ordinary psychrometric formula

$$e + \Delta = e'_{T_i'} - A(T_i - T_i')$$

and

$$e = e'_{T_0'} - A(T_0 - T_0')$$

$$\therefore \Delta = e'_{T_i'} - e'_{T_0'} - A[(T_i - T_i') - (T_0 - T_0')].$$

As before, for the small fluctuations in T_i' we may write

$$e'_{T_i'} = \alpha + \beta T_i'$$

$$e'_{T_0'} = \alpha + \beta T_0'.$$

$$\therefore \Delta = \beta \frac{\delta A H}{\sqrt{\xi^2 + \omega^2}} \sin(\omega t + \phi) - A \frac{H(\xi - \delta A)}{\sqrt{\xi^2 + \omega^2}} \sin(\omega t + \phi)$$

$$= \frac{AH}{\sqrt{\xi^2 + \omega^2}} (\beta\delta - \xi + \delta A) \sin(\omega t + \phi)$$

by substituting the values of δ, ξ, and A in the expression $(\beta\delta - \xi + \delta A)$ it becomes evident that

$$(\beta\delta - \xi + \delta A) \equiv 0$$

and therefore $\Delta = 0$ at all times.

* The method by which ϵ may be made equal to ξ in the actual psychrometer in practice will be shown later.

So that, in order to obtain a constant and correct value of the vapour pressure from an aspiration psychrometer operating under unsteady conditions of temperature, it is only necessary to arrange the transient constant of the dry bulb equal to the effective transient constant of the wet bulb.

Such a psychrometer may be called a Compensated Psychrometer.

The Technical Arrangement of the Compensated Psychrometer.

ϵ may be made equal to ξ by adjusting the relative ventilations of the dry and wet bulb thermometers.

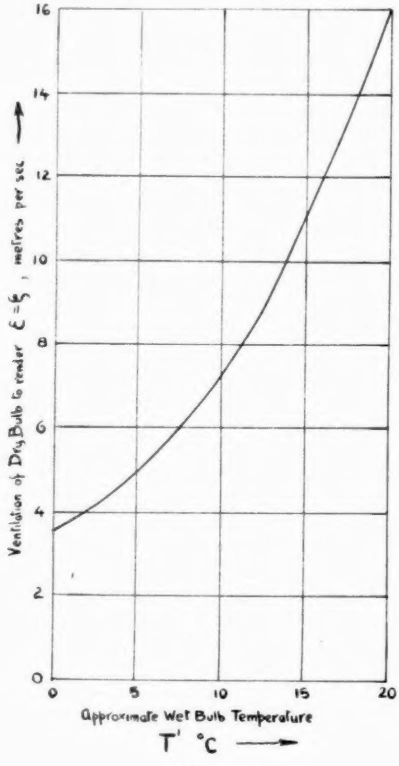


Fig. 8.

In order, however, that the vapour pressure may be read off tables in the usual fashion, it is evident that the psychrometric constant A must

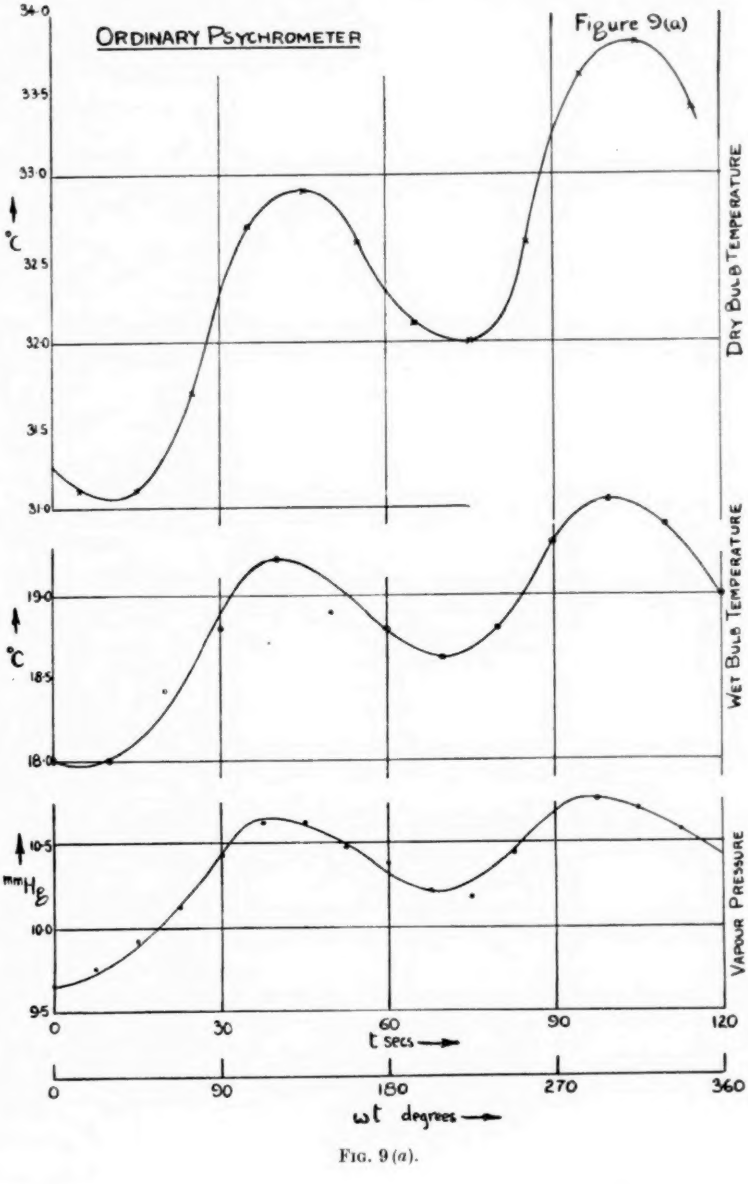

ORDINARY PSYCHROMETER
Figure 9(a)
34·0
33·5
33·0
32·5
32·0
31·5
31·0
°C
DRY BULB TEMPERATURE
19·0
18·5
18·0
°C
WET BULB TEMPERATURE
10·5
10·0
9·5
mm Hg
VAPOUR PRESSURE
0
30
60
90
120
t secs
0
90
180
270
360
ωt degrees

FIG. 9 (a).

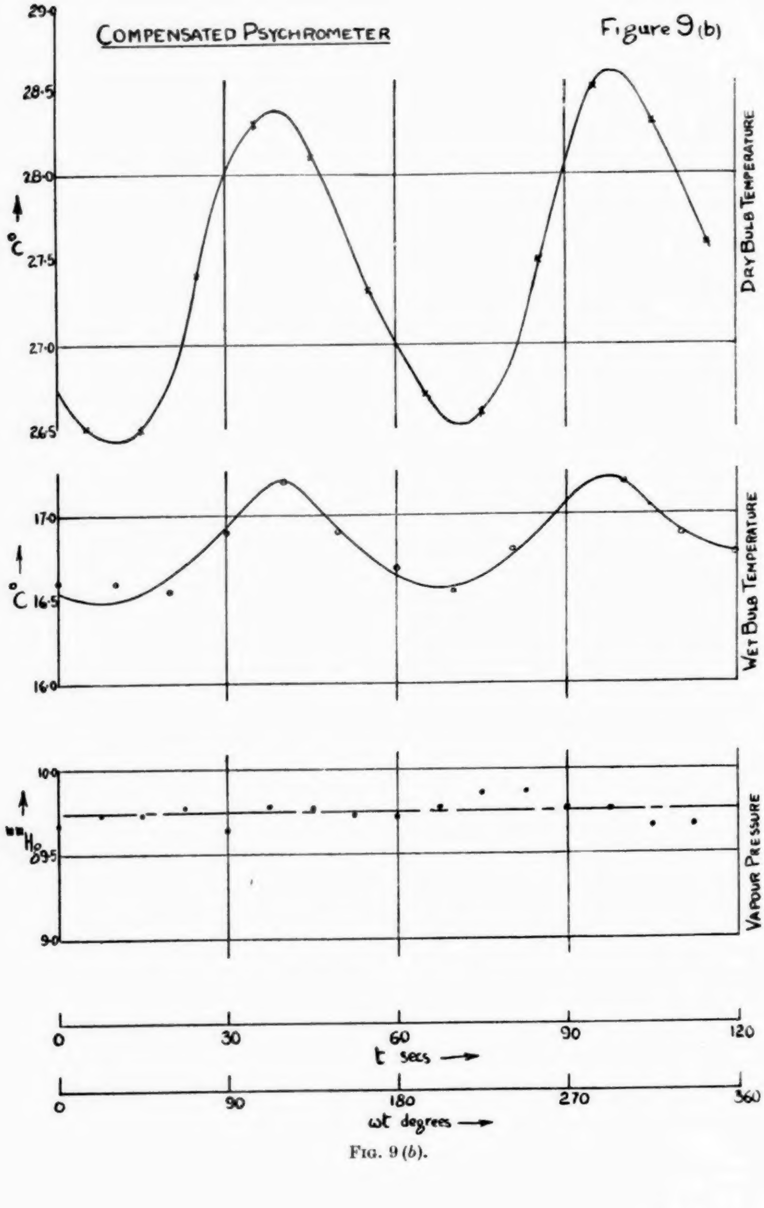

COMPENSATED PSYCHROMETER
Figure 9 (b)
29.0
28.5
28.0
27.5
27.0
26.5
°C
DRY BULB TEMPERATURE
17.0
16.5
16.0
°C
WET BULB TEMPERATURE
10.0
9.5
9.0
mm Hg
VAPOUR PRESSURE
0
30
60
90
120
t secs
0
90
180
270
360
ωt degrees

Fig. 9 (b).

remain the same, and this means that the ventilation of the wet bulb must be constant at all times.

Now

$$\xi = \frac{m_2 r L}{PC_1}(A + \beta)$$

and

$$\epsilon = \frac{m_3 C_p}{C}.$$

The ventilation of the wet bulb is constant, therefore ξ is a function of the mean wet bulb temperature alone, and ϵ is a function of the dry bulb ventilation alone. So that, evidently, for each wet bulb temperature there is an appropriate dry bulb ventilation which will render $\xi = \epsilon$.

For the two identical thermometers whose pertinent characteristics are given in fig. 4, a chart has been prepared showing the dry bulb ventilation necessary to effect compensation at various wet bulb temperatures. This is given in fig. 8, and applies to the particular thermometers used by the author, a constant wet bulb ventilation of 4 m./sec. and an atmospheric pressure of 650 mm. of mercury—the pressure at which the experiments were carried out. Similar charts can be prepared for any pair of thermometers (not necessarily similar), any constant wet bulb ventilation, and any pressure.

It will be seen from fig. 8 that for high wet bulb temperatures the ventilation of the dry bulb to effect compensation is rather high. The

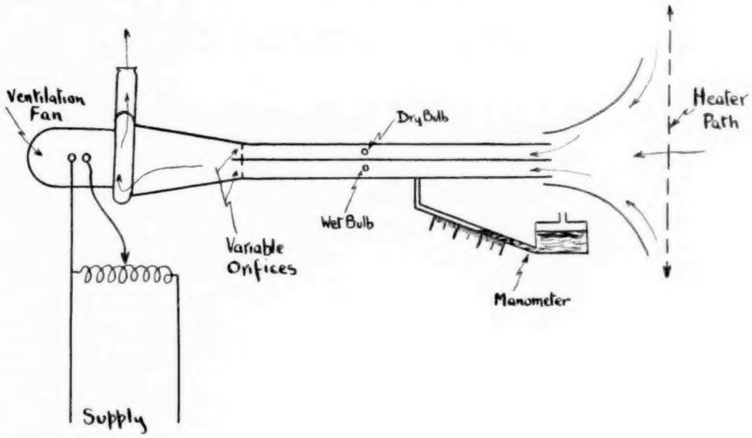


Fig. 10.

whole range of dry bulb ventilations can, however, be reduced by making the dry bulb much smaller than the wet bulb.

In the author's experimental compensated psychrometer shown in fig. 10 the ventilation past the wet bulb could be kept constant at 4 m./sec. while that past the dry bulb could be adjusted to the required value by means of the variable orifices and fan speed control. In order to demonstrate the efficacy of the arrangement an artificial fluctuation of temperature was achieved by moving an electric heating device, in simple harmonic motion, to and fro in front of the flared entrance to the psychrometer.

The curves in fig. 9 (*a*) show the results of such tests with an ordinary psychrometer (ventilation of dry bulb the same as that of wet bulb); fig. 9 (*b*) with the compensated psychrometer ($\epsilon = \xi$).*

The constancy of the vapour pressure values from the compensated psychrometer contrast excellently with the fluctuating values obtained on the ordinary instrument.

* The method of using the compensated psychrometer is to run it first as an ordinary psychrometer and obtain the approximate wet bulb temperature, then adjust the ventilation of the dry bulb to the value corresponding to this temperature.

THE CHROMOSOME NUMBERS OF BERBERIS.

By Malcolm H. Giffen,

Department of Botany, South African Native College, Fort Hare.

(Read March 18, 1936.)

This investigation of the chromosome numbers of the Genus Berberis was undertaken in 1928, the material being collected in the Royal Botanic Gardens, Kew, the Cambridge University Botanic Gardens, and the Royal Botanic Garden, Edinburgh. I am greatly indebted to the Directors of these Gardens for facilities extended to me, and wish to express my thanks for their kindness.

Root tips were fixed about 11 a.m. and buds from 12 noon until 2 p.m., the root tips usually in Chromo-Acetic acid of various strengths, the most satisfactory being:

2 per cent. Chromic Acid . .	7 parts.
10 per cent. Acetic Acid . . .	3 parts.

For buds, Formol-Chromo-Acetic Acid (Karpechenko's modification of Navashin's Fluid) and Flemming's Stronger solution gave very good results.

The material was embedded in paraffin wax and sections were cut 8 μ or 10 μ in thickness and stained in Haidenheim's Iron-Alum Haematoxylin or Newton's Gentian Violet.

The following table gives the chromosome numbers of all species of Berberis so far investigated.

It will be seen from the table, that in all cases except one, the chromosome number is 14 (haploid) and 28 (diploid). The aberrant number is found in *Berberis buxifolia*. Tischler (1928) records for this species the haploid number of 28. My preparations from plants in the Cambridge University Botanic Gardens show the chromosome number of 14 in the reduction division of pollen mother-cells. It therefore appears possible that the plant from which Tischler obtained his material and made his counts is a tetraploid.

The development of tetraploid plants in Berberis is of great interest in view of the apparent stability of the genus. In looking through the lists

BERBERIS.

Name of Species.	Somatic.	Buds.	Investigator.
SUB-GENUS BERBERIS.			
B. acanthophylla	28		
B. aggregata	28		
B. aggregata, var. *Prattii*	28		
B. amurensis	..	14	
B. angulosa	28		
B. aristata	28		
B. atrocarpa	28		
B. beaniana	28		
B. brachypoda	28		
B. brevipaniculata	28		
B. buxifolia	..	14	Giffen.
		28	Tischler, 1928.
B. concinna	28		
B. cretica	28		
B. Darwinii	..	14	Giffen.
		14	Tischler, 1927, 1928.
		14	Himmelbauer, 1912.
B. dictophylla	28		
B. empetrifolia	..	14	Giffen.
		14	Tischler, 1927, 1928.
		14	Himmelbauer, 1912.
B. Franscisci-Ferdinandi	28		
B. Gagnepainii	28		
B. heterophylla	28		
B. ilicifolia	28		
B. integerrima	..	14	Tischler, 1928.
B. Julianae	28		
B. levis	..	14	
B. lycium	..	14	
B. polyantha	28		
B. pruinosa	..	14	
B. sinensis	28		
B. soulieana	28		
B. Thunbergii	..	14	Tischler, 1928.
B. virescens	28	..	Giffen.
B. vulgaris	28	..	Giffen.
		14	Tischler, 1928.
B. Veitchii	..	14	Tischler, 1928.
B. sp. (*verna*)	28	..	Langlet, 1928.
SUB-GENUS MAHONIA.			
B. (*Mahonia*) *aquifolium*	..	14	
B. (*Mahonia*) *aquifolium*, var. *Murrayana*, Hort.	..	14	

Name of Species.	Somatic.	Buds.	Investigator.
B. (*Mahonia*) *pinnata* . . .	..	14	
B. (*Mahonia*) *repens* . . .	..	14	Giffen.
		14	Tischler, 1928.
B. (*Mahonia*) *japonica* . . .	..	14	Tischler, 1928.
HYBRIDS.			
B. stenophylla, Hort.	28	..	Giffen.
(*B. Darwinii* × *B. empetrifolia*)		14	Tischler, 1927.
B. Darwinii × *B. empetrifolia* .	..	14	Himmelbauer, 1912.
Maho-Berberis Neubertii, Hort. (*B. Mahonia aquifolium* × *B. vulgaris*)	28	..	Giffen.

of Chromosome numbers given in Tischler (1922) and Gaiser (1926, 1930, 1930 *b*, 1933), few genera show so little polyploidy in so many species.

The pollen formation of those species which were examined as buds, proceeded regularly. In practically all cases there were no lagging chromosomes or other signs of hybridity. It is thus almost certain that these species are of pure descent, the few abnormalities observed probably being caused by imperfect fixation.

The inter-generic hybrid, *Maho-Berberis Neubertii*, a cross between *Berberis vulgaris* and *Mahonia aquifolium*, is interesting from the fact that it does not produce flowers, a condition brought about, according to Tischler (1922), by some physiological factor.

SUMMARY.

1. The chromosome numbers of forty species of Berberis and its subgenus Mahonia have been investigated.

2. The haploid number of the genus is 14.

3. Only one species, *B. buxifolia*, so far, shows polyploidy, the haploid numbers of 14 (Giffen) and of 28 (Tischler) being recorded.

4. Somatic divisions were observed in the root tips of the flowerless inter-generic hybrid *Maho-Berberis Neubertii*, which also has the haploid number of 14.

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CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.*

12. *Some Diatoms from the Victoria Falls.*

By Florence Rich, M.A., F.L.S.

(Communicated by Miss E. L. Stephens.)

(With Plates VIII, IX, X.)

(Read April 15, 1936.)

The ensuing account is not a description of Diatoms systematically collected as representative of the locality of the Victoria Falls, but rather of a chance collection that came under the author's notice and of which the history is as follows. In 1929 Professor McClean of Cardiff sent to the Botanical Department of Queen Mary College, London, a small bottle containing washings from a gathering of one of the Podostemaceae (*Dicraea* sp.) † ; this collection had been made by Professor W. M. Tattersall just above the Falls, not very far from the Victoria Falls Hotel. A cursory glance showed that the washings contained many algae, and were particularly rich in Diatoms, and, as no account of the Diatoms of the River Zambesi had as yet been published, it was considered that a detailed examination would prove of interest. It was not, however, until 1935 that the opportunity for a full investigation occurred. Several papers containing descriptions of the Diatoms of South and Central Africa have been produced, and it was, therefore, not to be expected that much that was new had been left to be discovered. About sixty different species and varieties have been identified from the sample now investigated, and nearly all of these were previously well known, and had

* From the Botanical Department, Queen Mary College, University of London. The author is indebted to the Carnegie Corporation for the Advancement of Research for a grant, made through the Research Grant Board of the Union of South Africa, in aid of this work.

† Dr. M. A. Pocock says that these plants grow on rocks at the east side of the Falls, in water or spray. When the river is high and they are submerged the flow is rapid.

already been recorded from South or Central Africa. The only Diatoms that appear to be at all out of the ordinary are:—*Navicula distincta* G. S. West, previously recorded only from Lake Tanganyika, *Gomphonema subapicatum* f. *curta* Fritsch and Rich, hitherto known only from Griqualand West, new forms of *Navicula gastrum* Ehr., of *Cymbella grossestriata* Müll. var. *obtusiuscula* Müll., of *Cymbella tumida* (Bréb.) Van Heurck, and of *Gomphonema intricatum* Kütz., a new variety of *Navicula gastrum* Ehr., and one new species, *Navicula stigmata*.

The asymmetric *Rhopalodias* and the *Gomphocymbellas*, which are characteristic of the East African Lakes, were not observed, but *Cymbella grossestriata* var. *obtusiuscula* Müll., known only from Lakes Rudolf and Molamba, N. Rhodesia, and Uganda, was fairly common. The Synedras were very common, as was also found to be the case in Natal and Griqualand West. The collection consisted in the main of species of *Synedra*, *Cymbella*, and *Cocconeis*, most of the other Diatoms being rare or rather rare.

The arrangement followed is that of Hustedt, 1930 (Die Süsswasserflora Mitteleuropas, Heft 10, Bacillariophyta). Except in the case of very wide-spread Diatoms references to existing literature and figures are given after the name. Figures have been drawn only when attention is directed to some unusual feature, or when it is considered that other figures are not readily accessible to South African readers.

The author wishes to record her thanks to Professor F. E. Fritsch for his valuable help.

Systematic Enumeration of the Species Observed.

A. CENTRICAE.

Genus *Cyclotella* Kützing.

Cyclotella Meneghiniana Kütz.

Lat., 17 μ; striae in 10 μ = 8.

Already recorded for Nyasa, Griqualand West, Natal, the Karoo, and Little Namaqualand, and Lakes Nakuru, Rudolf, and Edward.

Genus *Melosira* Agardh.

Melosira ambigua (Grun.) O. Müll.

Lat., 5–13·5 μ. About 18 pores in 10 μ.

Recorded for the Transvaal, and Lakes Nyasa, Tanganyika, and Naivasha.

B. PENNATAE.

Genus *Fragilaria* Lyngbye.

Fragilaria capucina Desm.; Hustedt, 1930, fig. 126.
Long., 29–42 μ; lat., 3–4 μ; striae in 10 μ = 14–16.

Fragilaria construens (Ehr.) Grun.; Hustedt, 1931, p. 156, fig. 670, *a, b, c.*
Long. 14–16 μ; lat., 9 μ; striae in 10 μ = ca. 12.

Fragilaria virescens Ralfs; Hustedt, 1931, p. 162, fig. 672, A, *b.*
Long., 18–33 μ.
A variety has been recorded from Angola.

Genus *Synedra* Ehrenberg.

Synedra biceps (Kütz.) Hustedt; Fritsch and Rich, 1929, p. 95, fig. 2, R–T.
Long., 345 μ; striae in 10 μ = 8.
Recorded from Griqualand West and N. Rhodesia.

Var. ***distenta*** Fritsch and Rich, 1929, p. 95, fig. 2, N–Q. In many individuals there was a slight distention of the valves just above the capitate ends, in this respect exactly resembling specimens from Griqualand West.

Synedra dorsiventralis O. Müller, 1910, p. 114. This Diatom, with several forms and varieties, was first described from Nyasa and neighbouring lakes. A few years later it was observed in Natal (see footnote, Fritsch and Rich, 1929, p. 114).

Forma ***angusta*** O. M. (Pl. VIII, A, B.)
Long., 60–100 μ; lat., 7·5–9 μ; striae in 10 μ = 11–12.
Precisely similar to the Nyasa form.

Var. ***sinuata*** O.M., 1910, p. 114. The concavity was usually not quite in the middle of the valve.

Formae longiores subcapitatae, O. M. (Pl. VIII, C.)
Long., 55–78 μ; lat., 8–10 μ; striae in 10 μ = 12.

Formae breviores rostratae vel cuneatae, O. M. (Pl. VIII, D.)
Long., 50 μ; lat., 11 μ; striae in 10 μ = 12.

Transitional diatom, Pl. VIII, E (see under *Synedra ulna*).

Synedra ulna (Nitzsch) Ehrenb. var. ***subaequalis*** Grun.; Fritsch and Rich, 1929, fig. 2, B.

Long., 360 μ; lat., 7·5 μ; striae in 10 μ = 9. This is a variety showing practically no tapering at all; the ends are faintly capitate, and there is a gap in the central striae.

Recorded from Nyasa and Griqualand West.

Form transitional between *S. ulna* and *S. dorsiventralis*. (Pl. VIII, E.)

Long., 150–250 μ; lat., 6–8 μ; striae in 10 μ = 10.

This form resembles *S. ulna* in being slightly tapering and in having about 10 striae in 10 μ. The central area is one-sided, there being a gap in the striae on one side only, just as in *S. dorsiventralis*. The ends are not capitate, but are slightly drawn out and rounded at the tips.

Recorded from Nyasa (see Müller, 1910, p. 113).

Synedra Vaucheriae Kütz. var. *truncata* (Grev.) Grun.; Hustedt, 1932, p. 194, fig. 689, *d*.

Long., 17 μ; lat., 4–5 μ; striae in 10 μ = 12–13.

Genus *Eunotia* Ehrenberg.

Eunotia pectinalis (Kütz.) Rab. var. *undulata* Ralfs; Hustedt, 1932, p. 298, fig. 763, *i*.

Long., 65–67 μ; lat., 7–8 μ; striae in 10 μ = 7.

Recorded from Nyasa, observed at Old N'gamo.

Forma *triundulata* Müll.

Long., 34 μ; lat., 7–8 μ; striae in 10 μ = 12. This form of var. *undulata* was first described from Nyasa.

Genus *Cocconeis* Ehrenberg.

Cocconeis placentula Ehr.; Hustedt, 1933, fig. 802, *a*.

Long., 50 μ; lat., 34 μ.

Recorded from Griqualand West, Cape Province, Angola, Natal, and Nyasa.

Var. *lineata* (Ehr.) Cleve; Hustedt, 1933, fig. 802, *d*.

Long., 42 μ; lat. 29 μ.

Recorded from Nyasa.

Genus *Achnanthes* Bory.

Achnanthes lanceolata, Bréb. var. *elliptica* Cl.; Hustedt, 1933, p. 410, fig. 863, *n*, *o*.

Long., 10 μ; lat., 6·5 μ; striae in 10 μ = 13. The type has been recorded from Nyasa and Angola.

Var. *rostrata* (Östrup) Hustedt, 1933, p. 410, fig. 863, *j–k*.
Long., 16·5–17 μ; lat., 7·5–8 μ; striae in 10 μ = 13–15.
The striae are nearly parallel; the ends slightly drawn out and capitate.

? *Achnanthes minutissima* Kütz. var. *cryptocephala* Grun.; Hustedt, 1930, p. 198, fig. 275.
Long., 8 μ; lat., 3·5 μ.

Genus *Amphipleura* Kützing.

Amphipleura pellucida, Kütz.: Hustedt, 1930, p. 218, fig. 321.
Long., 117 μ; lat., 4 μ.

Genus *Caloneis* Cleve.

Caloneis bacillum (Grun.) Mereschkowsky *forma*; *cf.* Hustedt, 1930, p. 236, fig. 360, *a*.
Long., 33 μ; lat., 7 μ. More pointed at the ends than in Hustedt's figure. Very few individuals seen.

Caloneis silicula (Ehr.) Cleve; Hustedt, 1930, p. 236.
Long., 67 μ; lat., 12 μ.
Recorded from Griqualand West and the neighbourhood of Nyasa.

Genus *Diploneis* Ehrenberg.

Diploneis subovalis Cleve, 1894, I, p. 96, Pl. i, fig. 27. (Pl. X, I.)
Long., 32–40 μ; lat., 16–25 μ; striae in 10 μ = 8–10.
Cleve remarks that *D. subovalis* resembles *D. ovalis* (Hilse) Cleve in its shape and large central nodule, but that its structure is that of *D. Smithii* (Bréb.) Cleve.

D. subovalis has previously been recorded from Northern Rhodesia (Erlandsson).

(The puncta, which are in double rows, are less conspicuous than in Pl. X, I.)

Genus *Stauroneis* Ehrenberg.

Stauroneis anceps Ehr.
Long., 34–66 μ; lat., 7·5–16 μ.
Recorded from the Holle River, Griqualand West, N. Rhodesia, and the Transvaal.

Genus *Navicula* Bory.

Navicula cuspidata, Kütz.

Long., 109 μ; lat., 25 μ.

Recorded from Little Namaqualand, Griqualand West, and L. Naivasha.

Navicula distincta, G. S. West. (Pl. IX, G.)

Long., 21–25 μ; lat., 14–17 μ; striae in 10 μ, 8. Rare.

Very few individuals were seen. The valves are broadly elliptical, with conspicuous striations, of which about 18 or 20 appear along each side of the valve, radiating in disposition. One or two of the median striations are relatively short, alternating with others of maximum length. The striations are beaded; G. S. West in his original description (1907, "Third Tanganyika Expedition," p. 155) says they "appear to be perfectly smooth," and Erlandsson (1928, p. 455) does not mention any deviation from this, but I can only think the granulation was overlooked.

There is a strong resemblance between the above species and *N. scutelloides* W. Sm., and *N. pseudoscutiformis* Hust.

Recorded from Tanganyika.

Navicula gastrum, Ehr. (Pl. IX, D.)

Long., 45–58 μ; lat., 20–23 μ; striae in 10 μ = 8–10. Rare.

The cells are relatively a little wider than those hitherto described, and the striae of varying length are not symmetrically disposed on the two sides of the central nodule. The outline of the valve is very like that of the figure given by Hustedt (1930, fig. 537).

Recorded for Tanganyika.

Formae. (Pl. IX, E, F.)

One individual slenderer than the type (50 $\mu \times 15$ μ) was observed, and another much larger (75 $\mu \times 25$ μ). These do not correspond with any known varieties, but amongst the few individuals seen no characters of varietal significance could be made out. In all cases the number of striae in the middle portion of the valve was about 9 in 10 μ, more towards the poles. The striae were obscurely punctate.

Var. nov. *bistigmata*. (Pl. X, J, K.)

Long., 50–59 μ; lat., 21–25 μ; striae in 10 μ, circa 10.

Valvis ellipticis lanceolatis polis productis late rotundatis, area centrali cum stigmatibus 2 unilateralibus, striis indistincte punctatis, radiantibus, medianis irregulariter longioribus et brevioribus.

The sides of the valves are not parallel, the ends are broadly rounded, and on one side of the central nodule are two isolated puncta. Very few

Naviculas are known showing two puncta like this, but *N. gastrum* var. *baicalensis* Skvortzow, a variety of a different shape, possesses them.

Navicula placentula (Ehr.) Grun.; Hustedt, 1930, p. 303, fig. 532.

Long., 65 μ; lat., 25 μ. Very rare.

Striae radial all the way.

Recorded from Nyasa.

Navicula pupula Kütz.

Long., 44 μ; lat., 10 μ. Very rare.

Recorded from Griqualand West, Little Namaqualand, and Lakes Rudolf and Tanganyika.

Var. *major* O. Müller, 1910, Table I, fig. 3.

Long., 66 μ; lat., 15–16 μ. Very rare.

Recorded from the neighbourhood of Nyasa.

Navicula pusilla Smith; Donkin, Pl. iii, fig. 6, *b*.

Long., 49 μ; lat., 22 μ; striae in 10 μ (med.) = 11.

Recorded from N. Rhodesia.

Navicula radiosa Kütz.

Long., 80 μ; lat., 9 μ; striae in 10 μ = 11.

Recorded from N. Rhodesia, Natal, Tanganyika, and Nyasa.

Var. *tenella* (Bréb.) Grun.; Hustedt, 1930, p. 299.

Long., 37–50 μ; lat., 5–7 μ; striae in 10 μ = 16.

This variety comes very near *N. cincta* (Ehr.) Kütz. var. *Cari* Ehr.?, and Petersen (1928, p. 400) says he is not sure that the two can be kept distinct.

Recorded from Little Namaqualand.

Navicula stigmata sp. nov. (Pl. IX, A–C.)

Long., 40–48 μ; lat., 20–21·5 μ; striae in 10 μ = 12–13, puncta in 10 μ = ca. 15.

Valvis ellipticis lanceolatis lateribus in media parte parallelis polis productis late rotundatis, area axiali angusta lineari, area centrali indistincta transverse ampliata cum stigmate singulo unilaterali, striis subtilibus punctatis radiantibus, medianis irregulariter longioribus et brevioribus.

For a short distance, in the middle of the valve, the sides are parallel; there is an isolated punctum on one side of the central nodule, and the striae are fine and punctate. In some individuals the separate puncta of the striae were much more noticeable than in others.

In shape this Diatom resembles *N. amphibola* Cleve, but it differs in having an isolated stigma, and in its finer striae. Comparison should also be made with *N. gastrum* var. *turgida* Müll. f. *stigmata* Müll., which

mainly differs from the present variety in its shape, the sides being strongly convex and not parallel.

Two forms can be distinguished, in one, Pl. IX, A, the poles are very bluntly rounded; in the other, Pl. IX, B, the poles are more tapering.

Navicula viridula Kütz. (Pl. IX, L.)
Long., 75–78 μ; lat., 15–16 μ.
About 5 short striae in the middle on each side.
Recorded from Nyasa and Griqualand West.

Genus *Pinnularia* Ehrenberg.

Pinnularia acrospheria, Bréb.
Long., 80 μ; lat., 12–13 μ. Very rare.
Recorded for Natal and L. Naivasha.

Pinnularia interrupta W. Sm. (Pl. IX, J.) This diatom has been figured as the rounded ends are a little wider than is usually the case. Long., 66 μ; lat., 11–12 μ; striae in 10 μ = 10–11. It is very similar to *P. mesolopta,* to which it is evidently closely allied. Very rare.

Forms of this species are very widely distributed in S. Africa (see Fritsch and Rich, 1924, p. 105).

Pinnularia mesolepta (Ehr.) W. Smith. (Pl. IX, K.)
Long., 59 μ; lat., 10 μ. Rare.

The diatom found so closely resembles the figure of the type (Pascher, 1930, fig. 575, *a*) that it seems unnecessary to consider it a *form*; it has, however, been drawn to show the slight tapering from the middle of the valve to the end, and the produced apices which can scarcely be described as "distinctly capitate."

Recorded from Natal, Cape Province, and varieties from Nyasa.

Pinnularia microstauron (Ehr.) Cleve *forma*. (Pl. IX, I.)
Long., 76 μ; lat., 14·5 μ; striae in 10 μ = 9–10.

The sides of the valve are parallel, and the apices are only slightly capitate and scarcely wider than the rest of the valve. This form is broader than the type.

Pinnularia stauroptera Grun. var. *gracilis* Grun. (now included in *P. gibba* Ehr.). (Pl. IX, H.)
Long., 118 μ; lat., 10 μ; striae in 10 μ = 9. Very rare.

Very similar to *P. stauroptera* var. *interrupta* Cl., which has been recorded from Weltevreden West (Transvaal).

Pinnularia (*Navicula*) *viridis* (Nitzsch.) Ehr.

Long., 118–143 μ; lat., 17–24 μ; striae in 10 μ=9–10. The sides of the valve are sometimes parallel, sometimes slightly convex in the middle.

Recorded from Nyasa and the Cazengo District.

Genus *Amphora* Ehrenberg.

Amphora ovalis Kütz. var. *libyca* Ehr. *forma* as in Kenya; Rich, 1932, p. 253, fig. 3, C.

Long., 31–42 μ. Very rare.

Recorded for Kenya and Tanganyika.

Var. *affinis* Kütz.; Van Heurck, Pl. i, fig. 2.

Long., 57 μ; striae in 10 μ=11. Very rare.

Other forms of *A. ovalis* were also present.

Genus *Cymbella* Agardh.

Cymbella affinis Kütz. (Pl. X, D, E.)

Long., 30–38 μ; lat., 9 μ; striae in 10 μ=10–11.

One isolated dot at the apex of the midmost stria on the ventral side. (It is now thought that some of the forms from Griqualand West recorded under the name of *C. turgidula* really belong to *C. affinis*. The abnormality depicted by Fritsch and Rich, 1924, fig. 7, F, was observed in many instances in the sample from the Victoria Falls.)

Cymbella aspera (Ehr.) Cleve; Hustedt, 1930, p. 365, fig. 680.

Long., 133–134 μ; lat., 29–32 μ; striae in 10 μ=8–9. Very rare. Only a few individuals were seen but they corresponded exactly to Hustedt's figure. The puncta composing the striae were small and well set apart. The axial area was moderately wide, slightly enlarged round the central nodule.

Recorded from N. Rhodesia, and a variety from Nyasa.

Cymbella cymbiformis Kütz.; Hustedt, 1930, fig. 672.

Long., 67 μ; lat., 15 μ; striae in 10 μ=8 (mid.), 10 (pol.). Rare. Striae beaded, the central one on the ventral side with an isolated dot.

Recorded for Nyasa.

Cymbella Ehrenbergii Kütz. var. *pumila* Meister *forma.* (Pl. X, F.)

Long., 80 μ; lat., 27 μ; striae (med.) in 10 μ=5 (dors.), 9 (ventr.). Very rare.

This *Cymbella* resembles the allied *C. lata* Grun. in the slightness of its asymmetry and its broadly truncate ends ; it has, however, fewer and coarser striae, and is larger. It agrees well with Meister's description

(1912, p. 187) of var. *pumila*, but differs from his figure (Table XXXI, fig. 20) in its broader ends. It should be noticed that the striae are more numerous on the ventral side; they are slightly radiate throughout, and are obscurely punctate. The axial area is narrow, slightly dilated round the central nodule.

Not previously recorded for Africa, though *C. cucumis* A. Schm., which resembles *C. lata*, was found by Müller in Nyasa.

Cymbella grossestriata Müll. var. nov. *curta*. (Pl. X, C.)

Long., 25 μ; lat., 8–9 μ; striae in 10 μ (dors.) 7–8, (ventr.) 6. Differt a typo cellulis minoribus, polis non productis.

Not only is this variety smaller than the type, but it is also of a slightly different shape, the apices not being drawn out. It is not unlike var. *Tanganyikae* West in shape, but the striae are not so coarse.

Var. *obtusiuscula* Müll. (Pl. X, B.)

Long., 30–42 μ; lat., 9–10 μ; striae in 10 μ (dors.) 6–7, (ventr.) 5–6. Rather common.

The individuals now found resemble the variety described by Müller (1905, p. 154, t. 1, fig. 13) in their half-moon shape and bluntly rounded apices, and having the dorsal margin slightly concave towards the poles. Müller gives no range of dimensions, merely 33 μ for the length and 10 μ for the width; the present material furnishes plenty of specimens which enable the range to be extended.

Recorded for Lakes Nyasa, Uganda, Tanganyika, Naivasha, and Rudolf.

Forma *major*.

Long., 50–60 μ; lat., 13·5–16 μ; striae in 10 μ (dors.) 6–7, (ventr.) 5–6.

Other individuals linking var. *obtusiuscula* with this form were present, but so many of those measured were persistently just under 60 μ in length that they are considered worthy of having attention drawn to them.

Cymbella tumida (Bréb.) Van Heurck; Hustedt, 1930, p. 366. (Pl. X, G.)

Long., 58–85 μ; lat., 18–21 μ; striae in 10 μ = 7–8. Rather rare.

This Cymbella is characterised by the stigma which lies on the ventral side of the central nodule. Some of the striae towards the centre were observed to be of unequal length both dorsally and ventrally; Hustedt (1930, fig. 677) shows a more gradual diminution of length, with one short stria on the dorsal side.

Forma nov. *major*. (Pl. X, H.)

Long., 118 μ; lat., 24 μ; striae in 10 μ = 7. Very rare. Larger than the type.

Cymbella turgida (Gregory) Cleve; Hustedt, 1930, p. 358, fig. 660.

Long., 61–84 μ; lat., 17 μ; striae in 10 μ = 7 (dors.).

Previously recorded for Nyasa.

Cymbella turgidula Grun. *forma.* (Pl. X, A.)

Long., 48–56 μ; lat., 9–10 μ; striae in 10 μ (med.) = 8–10. Common.

Valves with a convex dorsal margin and obtusely rounded ends. Ventral margin almost straight, very slightly gibbous in the middle. Axial area narrow, scarcely enlarged round the central nodule. Striae in the middle on the dorsal side usually 9 in 10 μ, finely punctate; the two median striae on the ventral side end in an isolated dot. *C. turgidula* is nearly related to *C. affinis*, but is larger and has 2 puncta below the central nodule (Cleve, 1894, I, p. 171). The diatom now observed is placed as a form of this species, as in shape it does not resemble the figure given by Hustedt (1930, fig. 670).

Genus *Gomphonema* Agardh.

Gomphonema abbreviatum, Kütz.; Hustedt, 1930, p. 379, fig. 722.

Long., 17–19 μ; lat., 4–4·5 μ; striae in 10 μ, ca. 13. A very small diatom, with no isolated dot.

Gomphonema apiculatum (Ehr.) Cleve, 1893, Pl. iii, fig. 20.

Long., 22–27 μ; lat., 5–6 μ. Very rare.

There is an isolated dot on one side, with a short stria opposite.

Gomphonema brachyneura Müller; 1905, Tab. I, fig. 7.

Long., 36–43 μ; lat., 6–7 μ; striae in 10 μ = 11–12. Rather rare. See Fritsch and Rich, 1924, p. 387.

Recorded for Nyasa and Natal.

Gomphonema intricatum Kütz.; Hustedt, 1930, p. 375. (Pl. VIII, G.)

Long., 52–75 μ; lat., 8·5–11 μ; striae in 10 μ = 9–10. Rather rare.

Recorded for Nyasa, Griqualand West, and Madagascar.

Forma nov. *latior.* (Pl. VIII, F.)

Long., 66–80 μ; lat., 13–14 μ; striae in 10 μ = 7–8. Typical as regards shape, but wider than any form or variety hitherto described.

Gomphonema lanceolatum Ehr. var. *insignis* (Greg.) Cleve. (Pl. VIII, J, K.)

Long., 27–36 μ; lat., 6–8·5 μ; striae in 10 μ = 8–10. According to Cleve *G. lanceolatum* is nearly akin to *G. gracile* Ehr., and some of its forms are very similar to forms of *G. subclavatum* Grun.

Recorded for Nyasa.

Gomphonema parvulum (Kütz.) Grun. var. *micropus* (Kütz.) Cleve; Hustedt, 1930, p. 373. (Pl. VIII, H, I.)

Long., 25–28 μ; lat., 7 μ; striae in 10 μ = 11–12. Rather rare. There is a short stria opposite the isolated dot.

This variety has been recorded from Great Namaqualand and Nyasa; forms of the type have also been recorded from Griqualand West.

Gomphonema subapicatum Fritsch and Rich forma *curta* Fritsch and Rich, 1929, p. 109, fig. 6, C.

Long., 42 μ ; lat., 11·5 μ. Rare.

Precisely similar to the form observed in Griqualand West.

Genus *Epithemia* Brébisson.

Epithemia zebra (Ehr.) Kütz.

Long., 32–50 μ; lat., 9 μ.

Recorded from Griqualand West and N. Rhodesia.

Genus *Rhopalodia* O. Müller.

Rhopalodia gibba (Ehr.) O. Müll.; Hustedt, 1930, p. 390, fig. 740 Rather common.

Recorded from several places in S. Africa.

Rhopalodia gibberula (Ehr.) O. Müll. f. *crassa* O. Müll.

Long., 30 μ. Costae in 10 μ, ca. 5. Very rare.

Recorded from L. Rudolf.

Rhopalodia parallela (Grun.) O. Müll.; Hustedt, 1930, p. 389, fig. 739.

Long., 150–170 μ. Rather common.

Recorded from Nyasa, Uganda, and L. Naivasha.

Genus *Nitzschia* Hassall.

Nitzschia amphibia Grun.; Fritsch and Rich, 1929, fig. 10, J.

Long., 11–18 μ; lat., 5 μ; puncta in 10 μ = 9–10. Very similar in shape to *N. fonticola*, Grun. (Hustedt, 1930, p. 415, fig. 800), but with more carinal dots in 10 μ.

Recorded for Nyasa, Little Namaqualand, N. Rhodesia, and Griqualand West.

Nitzschia tryblionella Hantzsch var. *victoriae* Grun.; Hustedt, 1930, p. 399, fig. 758.

Long., 41 μ; lat., 17 μ; costae in 10 μ = 5–6. Very rare.

Recorded for Nyasa. The type recorded from Griqualand West.

Genus *Cymatopleura* W. Smith.

Cymatopleura solea (Bréb.) W. Sm.

Long., 63–202 μ; lat. (med.), 14–29 μ. Rather rare.

Recorded for Nyasa, Angola, N. Rhodesia, and Victoria Nyanza.

Genus *Surirella* Turpin.

Surirella biseriata Bréb. var. *subparallela*; Meister, 1912, p. 225, Tab. XLII, fig. 3.

Long., 160 μ; lat., 32 μ. Very rare.

Recorded for L. Edward.

? *Surirella tenera* Greg.: Hustedt, 1930, fig. 853.

Long. 101 μ; lat., 33 μ. This determination is doubtful, as the characteristic little projection was not observed.

Recorded for Nyasa and Victoria Nyanza.

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EXPLANATION OF PLATES.

PLATE VIII.

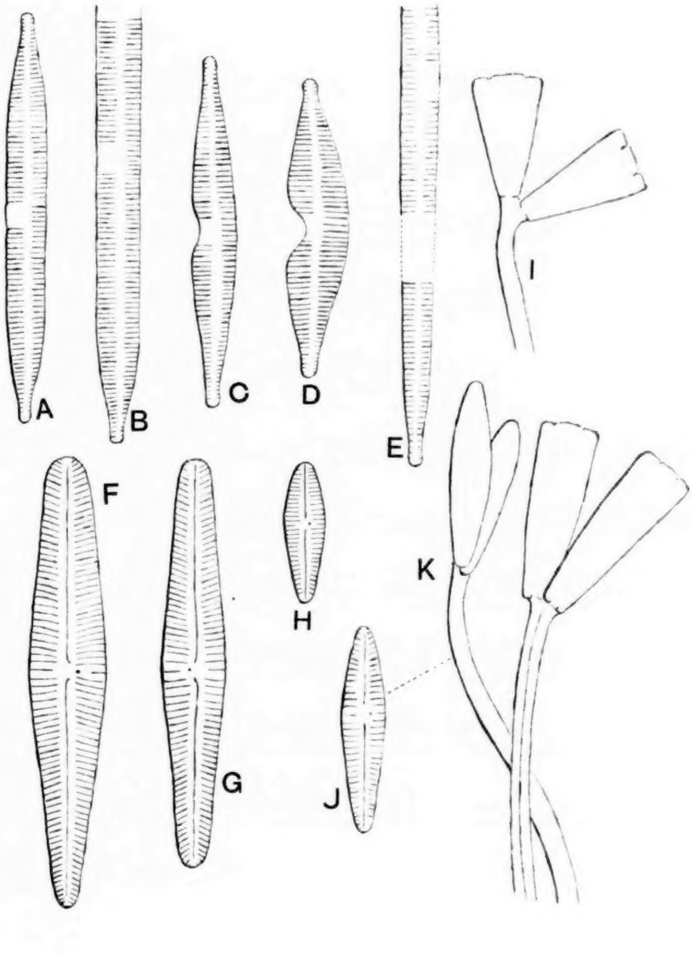
A, B. *Synedra dorsiventralis* O.M. f. *angusta* O.M. C. *S. dorsiventralis* var. *sinuata* O.M., and *forma* D. E. Transitional form between *S. ulna* and *S. dorsiventralis*. F, G. *Gomphonema intricatum* Kütz. (F. forma *latior*). H, I. *Gomphonema parvulum* (Kütz.) Grun. var. *micropus* (Kütz.) Cleve. J, K. *Gomphonema lanceolatum* Ehr. var. insignis (Greg.) Cleve. All × 900.

PLATE IX.

A–C. *Navicula stigmata* sp. nov. D. *Navicula gastrum* Ehr. E, F. Ib. formae. G. *Navicula distincta* G. S. West. H. *Pinnularia stauroptera* Grun. var. *gracilis* Grun. (= *P. gibba*). I. *Pinnularia microstauron* (Ehr.) Cleve forma. J. *Pinnularia interrupta* W. Sm. K. *Pinnularia mesolepta* (Ehr.) W. Sm. L. *Navicula viridula* Kütz. All × 900.

PLATE X.

A. *Cymbella turgidula* Grun. forma. B, C. *Cymbella grossestriata* Müll (B. var. *obtusiuscula* Müll, C. var. *curta*). D, E. *Cymbella affinis* Kütz. F. *Cymbella Ehrenbergii* Kütz. var. *pumila* Meister forma. G, H. *Cymbella tumida* (Bréb.) Van Heurck (H. forma *major*). I. *Diploneis subovalis* Cleve. J, K. *Navicula gastrum* Ehr. var. *bistigmata* var. nov. All × 900.



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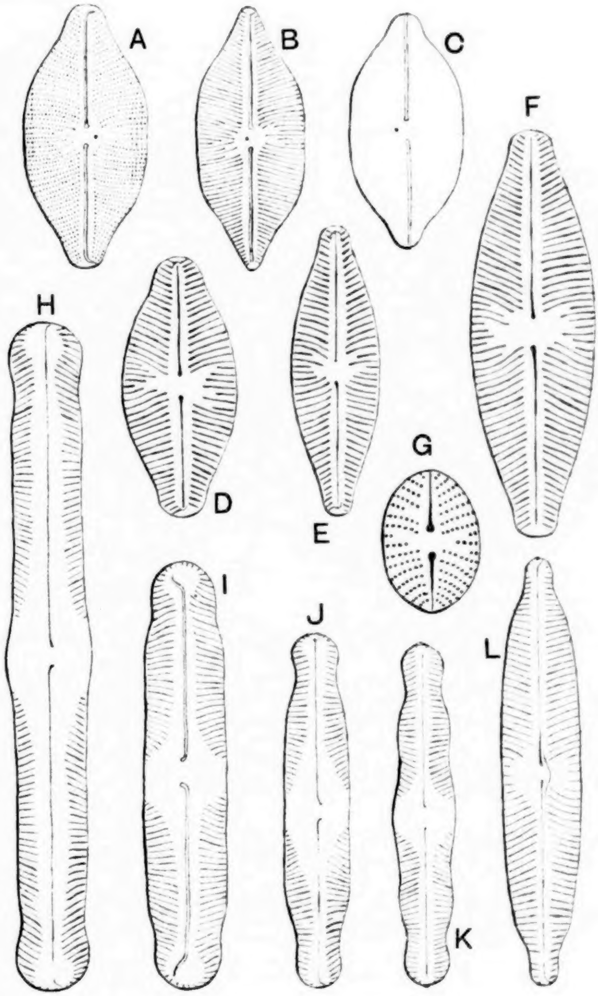

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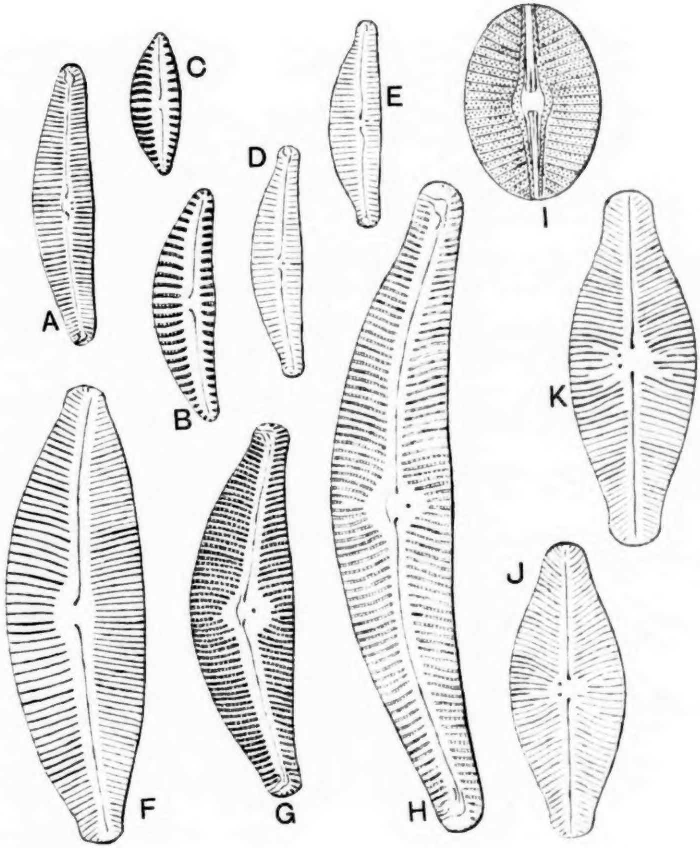

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THE CONTRIBUTIONS OF WESTERN CIVILISATION TO MODERN KXATLA CULTURE.

By I. SCHAPERA.

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The following analysis deals with changes produced in the culture of a South African tribe as a result of its contacts with Western civilisation. The information upon which it is based was obtained in the course of several visits to the tribe extending over the years 1929–1934, and covering in all a period of about sixteen months spent in the field.* The writer has already published some account of the present-day life of these natives, and of the methods employed by him in his investigations.† The present account is devoted more particularly to the actual process of acculturation and its effects.‡ It is not possible here to do more than touch briefly upon certain outstanding features of this process, and for more detailed discussions of some of the changes commented upon reference should be made to the papers mentioned. The outline given may serve, however, to convey some idea of the way in which this tribe has responded to the impact of Western civilisation, and so contribute towards the understanding of culture contact in Africa and its consequences.

TYPES OF CONTACT.

The BaKxatla baxaKxafêla, the tribe here dealt with, belong to the Tswana (Chwana) complex of the Sotho cluster of South-Central Bantu. The tribes of this complex derive their subsistence from hoe-culture, animal

* Acknowledgments are due for financial and other assistance to the University of Cape Town, the International Institute of African Languages and Cultures, and the Bechuanaland Protectorate Administration.

† Cf. "Present-day Life in the Native Reserves," in *Western Civilization and the Natives of South Africa* (ed. I. Schapera. London, 1934: Routledge), pp. 39–62; "The BaKxatla baxaKxafêla: Preliminary Report of Field Investigations," *Africa*, vol. vi (1933), pp. 402–414.

‡ For a description of the technique employed in the study of this process, cf. "Field Methods in the Study of Modern Culture Contacts," *Africa*, vol. viii (1935), 315–328.

husbandry and hunting. They live in large central villages, by far the biggest of which is the tribal headquarters. They are organised into patrilineal but non-exogamous lineage groups (*dikxôrô* or *dikxotla*), each made up of related polygynous families. Men and women respectively are grouped into age-regiments (sing. *mophatô*), formed every few years after elaborate initiation ceremonies. The tribe is governed by a chief who is not only its ruler and supreme judge, but also its wealthiest man and principal magician. To assist him he has councils of various grades, of which one is a full tribal assembly of men. The dominant religious cult is ancestor-worship, coupled with a vague belief in a personified deity.

The BaKxatla have been in contact with Western civilisation for nearly a century. They lived originally in the Western Transvaal, but since 1869 have been settled in what is now Bechuanaland Protectorate. Here they occupy a proclaimed Reserve of their own. Even before they left the Transvaal they had been influenced to some extent by the Boer Voortrekkers, who reached that country about 1840. Since their settlement in the Protectorate they have encountered the forces of Western civilisation from an increasing variety of sources. The Dutch Reformed Church had established a Mission amongst them in the Transvaal. It followed them into Bechuanaland and has continued to labour among them ever since. Bechuanaland was proclaimed a British Protectorate in 1885, when all its native tribes came under the political supremacy of the Imperial Government. The first trading store among the BaKxatla was erected about the same time in their tribal capital, Mochudi. Now there are five in the Reserve, and several more outside its borders but within easy reach. The railway line from the Cape to Rhodesia also passes right through the Reserve, within five miles of Mochudi, thus making it easily accessible. Moreover, the BaKxatla themselves have tended more and more to visit European areas of settlement in the Union of South Africa in search of employment.

Contacts between the BaKxatla and Western civilisation have thus in the main taken place on two fronts, differing considerably in character.

1. Although no European may own land in the Reserve, a few people representing various European interests live and work there among the natives. These Europeans include Government officials, missionaries, doctors, traders and blacksmiths, with their families and assistants. Altogether they number not more than about 40 souls, in contrast with the 14,000 BaKxatla who inhabit the Reserve. The Reserve is also bounded on three sides by blocks of European farms, with whose occupants, however, the BaKxatla but seldom come into contact. In addition, European visitors, both official and private, are now so frequently seen in the Reserve

as no longer to arouse any special comment. But the average tribesman as a rule has little direct relationship with them.

2. Most of the able-bodied tribesmen go annually to work in the urban and rural areas of the Transvaal and other European settlements. Here they may come into contact with Western civilisation in its most developed South African form. Here also they encounter representatives of many other native tribes. They themselves are now a negligibly insignificant minority, and so scattered about that as a rule they can lead no corporate life at all.

In the early days of contact, relations between the BaKxatla and Europeans were not always friendly. The Boers in the Transvaal were held in great wonder and admiration, owing mainly to the obvious superiority of their weapons, implements and means of transport. But they treated the tribe so harshly that at last it sought independence and safety by migrating to Bechuanaland, then still beyond the boundaries of any European power. The subsequent acceptance of British protection was due in part at least to the fear of further Boer encroachment. Even then it was some time, and after occasional moments of friction, before Western civilisation in general ceased to be regarded as an unwelcome intruder.

At present relations between the BaKxatla and the Europeans living about them are on the whole peaceful. In their own Reserve, possession of which is legally secured to them, the BaKxatla feel relatively free and undisturbed. They are still conscious of the authority of their chief, and live under their own tribal institutions. Accordingly, they have the bearing of an independent people, even although they realise well enough that the local Europeans belong to the dominant political order. This realisation is greatly intensified in the European centres of employment. Here the native encounters in their most stringent form the many disabilities and discriminations which the Europeans of South Africa have developed as a protective measure against the more numerous native peoples. His personal freedom is restricted on all sides, and he must therefore defer humbly to the Europeans with whom he has to deal.

Mechanisms of Contact.

We must now consider what features of Western civilisation were brought to the native in the course of these contacts, the conditions under which he encountered them, the scale on which they were presented to him, and the duration of their influence.

Elements Introduced.—As shown above, Western civilisation reached the BaKxatla from two different sources: (*a*) direct, through the Europeans encountered in and about the tribal Reserve; and (*b*) indirect, through the

effects exercised upon the tribesmen working abroad. These may be dealt with in turn.

The direct sources as vehicles of Western civilisation brought a large variety of new traits to the BaKxatla. Europeans in general revealed to them new forms of dress and decoration, of material culture, and of speech. The early Boers in the Transvaal employed them as farm hands and occasionally also as allies in wars against other native tribes. In this way they obtained some knowledge of European farming and military methods and implements, and their first experience of working for white people. The missionaries introduced a new form of religion, with its associated ritual, morality, organisation and places of worship; a new system of education, and new forms of medical treatment. The Administration introduced its own officials, taxation in money, new laws and penalties for their breach, new courts and methods of procedure, and various services designed to promote economic advancement. The traders, again, brought in the material products of Western civilisation and a new system of trade.

On the other hand, many aspects of Western civilisation did not reach the native at home. The local white residents are too few and too detached to convey more than a superficial idea of European domestic and social life. Still less can they reflect adequately their national forms of social and political organisation. It is equally impossible for the natives in the Reserve to learn directly about the industrial civilisation of the Europeans, apart from the slight glimpses they obtain of it through modern forms of transport and a few other mechanical contrivances.

These missing traits of Western civilisation are fully presented only to the native who goes to work in the towns. There he encounters the white man's technical achievements in their most developed form; he is employed on the mines, in factories and in other great industrial undertakings; and he observes, not always as an outsider, the functioning of European political and social institutions. But all this he must leave behind him when he returns. It does not exist as yet in his own home environment, and cannot directly affect those who remain there.

Manner and Order of Presentation.—We may now consider how such elements of Western civilisation as reached the BaKxatla were presented to them. A distinction should first be made between resident and absentee influences even among the direct sources of transmission. The missionaries, traders and blacksmiths have all along made their homes among the people, living there for many years in some instances. On the other hand, it was not until about four years ago that Government officials first began to live in the Reserve. Previously they had merely visited it sporadically, for not more than a few days at a time.

Nor did the various European agencies and the elements they intro-

duced all appear simultaneously. Leaving aside for the moment the early contacts with Boer farmers in the Transvaal, and considering only the more important influences still at work in the Reserve, the obvious priority goes to the Mission, which has been among the BaKxatla since 1864. The missionaries in addition to evangelisation gradually undertook the education of the people. For many years no other European influence acted directly upon the BaKxatla in Bechuanaland, apart from a few stray hunters and travellers. It was not until 1885 that the British Protectorate was proclaimed, followed soon afterwards by the erection of the first trading store in Mochudi. By that time, however, the people had already begun to seek work in European areas, which they have continued to do in ever-increasing numbers. A Government Proclamation of 1891 applied to Bechuanaland as a whole the laws of the Cape of Good Hope, and limited in certain ways the powers of the chiefs. The railway to the north was built in 1896, while in 1899 an annual poll tax was imposed on all adult male natives. But apart from this, direct administrative intervention in the life of the BaKxatla for long remained comparatively slight. More recently many new features have been introduced. Facilities for appeal against the verdicts of the chiefs were provided in 1919. In 1920 a Native Fund was created to finance native education and economic development, and a Native Advisory Council of chiefs and other tribal representatives set up for the whole Territory. Veterinary services and agricultural demonstrators and shows followed soon afterwards, the direction of education was taken over, and, in 1931, resident Government officials were stationed in the Reserve. The Mission has for the past twelve years or so also provided medical services, and in 1932 erected a small hospital in Mochudi.

The European agencies differed also both in their motives for intervention in the life of the tribe, and in the attitude adopted towards the tribal culture. The aim of the Mission is easily defined. It seeks essentially to convert the heathen natives to Christianity. In the pursuit of this policy it seeks also to introduce a new system of morals and general behaviour conforming to Christian ideals, and uses education as an instrument through which the native may learn to read the Gospels. It further undertakes the secondary task of promoting the general social and material advancement of the people. The Administration is concerned primarily with the maintenance of law and order, and with meeting the cost of the necessary machinery. Such services as education and economic development were not seriously taken in hand until much later. The trader, in so far as he has any definable aim at all, is there to exploit the natives for his own economic benefit, and accordingly attempts to develop as good a market as he can for his wares.

The attitude adopted towards tribal life depends to a great extent

upon the motive for intervention. The Administration finds it advisable, in the interests of good government, to curtail the powers of the native authorities in regard to such matters as war, foreign policy and certain aspects of criminal jurisdiction. It also refuses to tolerate practices held to be "repugnant to the principles of natural justice and civilisation," such as ritual homicide and the punishment of witchcraft. It must be noted, however, that Bechuanaland became a British Protectorate not through conquest, but by treaty with the leading chiefs and in response to their own wishes. Consequently there was as little interference as possible with the customary forms of native government and jurisdiction, save in the directions just indicated. Indeed, the avowed policy of the Protectorate Administration is "to preserve the tribal authority of the chiefs and the laws and customs of the people, subject to the due exercise of the power and jurisdiction of the Crown, and subject to the requirements of peace, order and good government." The Mission, on the other hand, attempted in its early days to introduce Christianity along European lines, and to do away with everything savouring of "heathenism." It accordingly forbade its converts to practise all patently "uncivilised" usages, such as polygamy, the inheritance of widows, *boxwêra* and *bojale* (the male and female initiation ceremonies associated with puberty), *boxadi* (bride-wealth), and magic and witchcraft, whether or not opposed to the teachings of the Gospels. It is only quite recently that this uncompromising attitude has been somewhat modified, for reasons which will subsequently appear. The attack upon magic and witchcraft is supported by the European doctors and veterinary surgeons, who find in the practices of the magician one of the greatest obstacles to the adoption of their own special services. The traders are in general indifferent to tribal custom so long as it does not actively interfere with the conduct of their business. None of those in the Kxatla Reserve appears to have taken any active steps one way or the other.

In the pursuit of these respective aims and policies, the European agencies also employ different methods. The Administration has the power to impose its wishes upon the people through physical force. It has seldom been found necessary to do so, save when breaches of the law occur; but the knowledge that force can be used, if need be, undoubtedly acts as a powerful inducement in securing compliance with new laws and administrative changes. The officials realise also that services such as education, hygiene and economic development cannot simply be forced upon the people, and rely mainly upon precept and example; but they have not hesitated where necessary to use compulsion, *e.g.* in regard to checking or preventing the spread of stock diseases. The Mission, on the other hand, has to rely almost entirely upon persuasion and propaganda, and the

sanctions it introduces can affect only its followers. Both it and the trader are essentially dependent upon the goodwill of the native authorities, especially in the early days of contact. Consequently, they must try as far as possible to conciliate native opinion and avoid giving offence. More recently both have also felt able to fall back upon the protection and support of the Administration, and consequently to act somewhat more freely; but native goodwill still counts with them to a predominant extent.

Summarising briefly, we may distinguish four main phases of contact: an early period in the Transvaal, leading up to the withdrawal of the BaKxatla to Bechuanaland; a middle period, confined mainly to the introduction of what the Europeans regarded as indispensable religious, political and economic institutions, in the form of the Mission, the Pax Britannica, and the trader; a later period of relative quiescence, during which these institutions gradually established themselves in tribal life; and a modern period, only recently begun and by no means ended, of more intensive political, economic and social change.

We may finally note what aspects of Kxatla life were first affected by these various new influences. The main spheres of early contact were economic, religious and political. The impact was most marked in religion, where the differences between Christianity and the old cult of ancestor-worship were outstanding. Economic life was greatly affected by the introduction of European goods, by labour migration, and by taxation. Political life was on the other hand left largely untouched, except for the few changes already referred to. The social organisation was not directly affected, nor was social life generally, apart from the changes attempted by the Mission in regard to certain customs connected with marriage and other forms of domestic ritual. It was only after Western civilisation had been at work for some time that its influence began to extend to these other spheres as well, and that new elements were introduced to facilitate its general spread.

Acceptance of New Traits.

As a result of these contacts, certain traits of culture formerly possessed by the BaKxatla have either disappeared completely or appear to be doing so, others have been much or only slightly modified, and still others appear to have remained largely intact. Other traits, again, have been taken over wholly or in part from Western civilisation. Some have been widely accepted, others to only a limited extent. Why have these changes taken place, and why have they varied so much in their nature and effects?

We have to deal here with two main sets of problems: the acceptance of new traits of culture, and the displacement of old traits. They are in a

sense different aspects of the same problem, and cannot always be disentangled. But for the purposes of analysis it will be convenient to regard them as distinct. The problem of acceptance involves a discussion not merely of why certain traits of Western civilisation have been selected for acceptance, but also of why others which were also presented have been resisted or rejected. Displacement, again, is in part at least a consequence of acceptance, and may therefore be dealt with after it. We may then finally consider the lines along which the tribal culture as a whole has been adapted to the new situation.

Initial Acceptance.—Certain traits brought by the Europeans the BaKxatla had little option but to accept. This was particularly so with the first changes introduced by the Administration. Because of the power wielded by this agency, the chiefs had to forfeit some of their rights, and accept the delimitation of their Reserves, the introduction of white officials, and the building of a railway; while the people in general had to submit to taxation and to various laws affecting their freedom of conduct. The response here was therefore dictated partly by compulsion and fear of the consequences of disobedience. But in the main it seems to have been dictated by expediency. The Protectorate was proclaimed, among other things, to prevent a much-feared Boer expansion westwards from the Transvaal into Bechuanaland; and in order to obtain the security and the advantage of British protection the chiefs and their people were willing to sacrifice certain powers and liberties, and assume certain obligations.

The wares of the trader, on the other hand, were accepted readily, even eagerly, because of their general superiority to native products: they were more durable and efficient, and could be obtained without the effort of manufacture. It is not without significance that the goods most sought after in the early days were almost all better substitutes for corresponding native objects, *e.g.* guns in place of spears and clubs, ploughs in place of hoes, and metal goods generally in place of the crude native iron, clay and wooden products. Ornaments, too, such as beads and bracelets, exercised a considerable attraction, and were widely adopted. Other factors subsequently contributed to make trade goods indispensable and the trading store an established part of the tribal culture. Administrative effort, Mission activity, education, and the influence of contact with Europeans generally have led to a higher standard of living and to greater progress towards "civilisation." The range of goods purchased has accordingly increased very considerably. Dress material, blankets, men's wear, ploughs, pots, hatchets, spades, buckets, basins, mirrors, crockery, beads, ear-rings, matches, tobacco, salt, soap, tea, sugar and even bread all find a ready sale, and by many have come to be regarded as necessities rather than as luxuries. Ox-drawn wagons are bought by all who can afford them,

and in more progressive households one even notices European articles of furniture, such as beds, tables and chairs.*

The Mission had neither the force of compulsion nor the appeal of economic advantage or technical superiority. For nearly thirty years it laboured with but little success, making only a few converts and exercising no great effect upon tribal life generally. Then at last, in 1892, it achieved the notable triumph of securing the acceptance of Christianity as the official religion of the tribe through the conversion and baptism of Chief Lentswe (ruled 1875–1921). Some of his brothers had already adopted the new faith, but the tribe as a whole was still against it. It was only after a huge public meeting where the question was heatedly debated that Lentswe succeeded in getting his way. Since as chief he was also the great tribal rain-maker and magician, his example was a compulsory guide to the rest of the people. The marked encouragement he gave to the new religion, coupled with his abolition of many old ceremonies, has led in forty years to a condition where little active trace remains of the old religious system.

The ultimate acceptance of Christianity was therefore due mainly to the personal influence of the chief, by far the most important person in the tribe. The same factor has played a large part in the acceptance of other aspects of Western civilisation. Lentswe at first tended to oppose the introduction of civilising elements, fearing they would lead to the disintegration and corruption of his people. It was for this reason, *e.g.*, that he objected, albeit unavailingly, to the construction through his Reserve of a telegraph line (1890) and later of the railway (1896). But when he saw that penetration was inevitable, he altered his tactics, and eagerly accepted such elements as he thought would be of advantage to the tribe. Both he and his son, the ex-regent Isang, were men of exceptional ability and enterprise; and through sheer force of personality and the tremendous prestige attaching to them as chiefs were able to do much for the advancement of their people. They realised that Western civilisation was coming to stay, and, in the words of Isang, that "in adapting ourselves to this same civilisation lay our future as a nation." Lentswe's acceptance of Christianity was due in part at least to his hope that the missionaries would protect him from undue exploitation by other Europeans and would assist him in the progress of the tribe. He supported their educational activities, and also encouraged his men to seek work among the Europeans in order to buy useful objects. Isang during his regency (1921–1929) eagerly pushed on educational and economic development. He brought education under the immediate control of the tribe, caused a magnificent school building

* On these and other economic changes in Kxatla life, cf. the writer's paper "Economic Conditions in a Bechuanaland Native Reserve," *South African Journal of Science*, vol. xxx (1933), pp. 633–655.

to be erected in Mochudi at the tribal expense, and gave bursaries to promising scholars. He also carried out an extensive scheme of water-boring to meet one of the greatest needs of the Reserve, actively encouraged the acquisition of good ploughs by the people, and aimed generally at bringing them "to adopt the white man's methods in ranching and agriculture." That he did not meet with marked success in all his endeavours was not due to his lack of zeal.

Developments from Initial Acceptance.—The acceptance of these culture traits from the Europeans led in time to the disappearance or modification of existing institutions, and to the introduction or development of other new forms of culture. For the moment we shall deal with the latter only. They must be regarded as secondary developments resulting from the initial penetration of Kxatla life by Western civilisation. They accordingly represent a somewhat different aspect of acculturation from that already touched upon.

We may first notice the development of new forms of occupation at home. The presence of Europeans in the Reserve has led to the paid employment of Kxatla men and women as domestic servants, store assistants and "yard boys." Education has created a small class of teachers, while the Mission employs evangelists and elders. The widespread adoption of European methods of thatching, originally learned in the Transvaal, and the much more limited erection of rectangular dwellings in imitation of the local European residents, have given scope for professional thatchers, masons and carpenters. The almost universal adoption of European clothing, due largely to Mission pressure backed by the chiefs, has paved the way for the craft of dressmaking, practised only by certain women. Within the last few years, again, the Mission has trained and employs a printer, the Administration an agricultural demonstrator, and the hospital some female nurses. The chief has his secretaries and chauffeur, and there is even a professional taxi-driver plying between Mochudi and Johannesburg, a distance of some 200 miles.

Contact with Western civilisation has also extended the activities of the chief. Not only is he the agent and representative of the tribe in its dealings with Europeans generally. He is the local authority through whom the Government issues its notices and proclamations to the tribe, and he is expected to co-operate with the magistrate and other officials in all sorts of political, economic, social and educational schemes and developments. He is a member *ex-officio* of the Native Advisory Council, the School Committee and the Hospital Board, and the official tax collector of the Administration. His work is now actually more than he can decently cope with alone, but owing to his pivotal position in the life of the tribe nothing can be done without his active support. He receives a commission

on the tax he collects, and his income has further been supplemented by stand rents from the traders and tribute in cash from the men who have been working abroad.

Tribal legislation has increased considerably to cope with modern conditions. Lentswe officially abolished many old ritual practices and certain customs connected with marriage and other institutions. It has further been found necessary by the chiefs to control by a system of permits the sale of cattle and crops, and to regulate the shooting of big game; levies are raised to finance public works such as building schools and churches, or boring for water, themselves innovations; and on two occasions abortive attempts have been made to limit the drinking of beer. Isang even tried to enforce a sumptuary law forbidding the people to squander their money recklessly on European finery. It should also be added that the Administration has from time to time proclaimed laws of various kinds directly affecting the people, and so has imposed upon them further legal obligations.

The increasing demand for trade goods, the imposition of taxes by the Administration, and the occasional raising of levies by the chiefs have had far-reaching consequences. The BaKxatla have had in the first place to pass from a subsistence economy into a money economy, and to enter into a trading system quite different from anything which prevailed in their own culture. The only local source of income open to the great majority is the sale of their cattle and other produce to the traders. This formerly enabled most of them to provide for almost all their wants and obligations. But the great drop in values due to the world depression and to the restrictions imposed upon export into the Union, by far their most important market, has made it imperative to find some additional source of income. Labour migration, formerly practised mainly in order to purchase more expensive goods and meet tribal levies, has accordingly become indispensable as a means of maintaining the existing standard of living. The number of men away at work every year is now about 40 per cent. of the adult male population. Many of them ultimately find work as unskilled industrial labourers in the Witwatersrand and other areas of the Transvaal and neighbouring provinces; some go to the farms of the Western Transvaal, and others to the gold mines of the Witwatersrand. As a rule they go out in the first four months of the year, and many get back after six months or so in time to plough and to resume their other normal occupations. But there is also a marked tendency for more and more men to remain away for longer periods at a time. This labour migration, in turn, has affected tribal life in a variety of ways, some of which will be considered below.*

* On this topic generally, cf. the writer's paper, "Labour Migration from a Bechuanaland Native Reserve," *Journal of the African Society*, vol. xxxii (1933), pp. 386–397; vol. xxxiii (1934), pp. 49–58.

Christianity, to take another notable example, has not only added a new form of religious belief to the tribal culture. The organisation of the Mission, once it was successfully established, led to the erection of churches, to new vocations for evangelists and elders, to the establishment of local church councils which supervise the behaviour of church members. It has instituted catechism classes, introduced baptism, confirmation and communion services, and developed new forms of marriage and death ritual. Its hymns have provided a new and very popular form of music. It has created new sanctions for people breaking its moral rules and regulations. It has made Sunday a compulsory day of rest, and introduced the festivals of the Church calendar. It was for many years responsible for all the educational work in the tribe, building schools and appointing teachers; while more recently it has provided medical services, started a small bi-monthly journal in the vernacular, and encouraged "youth movements" for boys and girls. The missionary himself has become not only the head of the tribal Church, but also the confidential adviser and guide of the people in politics and other spheres of life as remote from religion.

Education, in turn, has led among other things to a spreading knowledge of English as a spoken language. We meet here with an instance where the tribe has pressed for a new trait even against the judgment of its European advisers. Some of the early missionaries insisted upon instruction in the vernacular, and refused to encourage the teaching of English. The chiefs, however, were anxious that English should be taught as thoroughly as possible, owing to its great economic value to those who would afterwards have to seek work among the Europeans. It was for this reason that Isang ultimately took education out of the hands of the Mission and placed it under the control of a tribal committee. English then became the principal medium of instruction in the schools. But since the Administration took over the full direction of education in 1930 more use has again been made of the vernacular, in accordance with modern educational theory but greatly to the regret of some BaKxatla. Nevertheless, many children in the Reserve now have a fair smattering of conversational English in addition to their own language. Most of the men who have been out to work can also speak some English or Afrikaans. Education further brought a knowledge of writing, with the result that letter-writing has come to play a considerable part in maintaining contact between the men working abroad and their relatives and friends at home.

Differential Acceptance.—We have spoken so far as if the acceptance of Western traits was uniform throughout the tribe. Actually there has been a good deal of individual variation. Some people are very conservative, while others have discarded many of the traditional customs and beliefs in favour of European institutions. The distribution of European traits

varies from an almost universal acceptance of clothing and certain other material objects to an almost negligible adoption of European standards of life and conduct in general. It is difficult to determine how far these variations are due to original differences in attitude towards Western civilisation, and how far they are the product of changing conditions. Certain obvious points can at once be made. The chiefs, as we have seen, actively encouraged the adoption of certain traits of civilisation. The magicians, on the other hand, have in certain directions been a powerful influence towards conservatism, if only because their livelihood depends upon maintaining in the minds of the people a belief in the efficacy of magic. The older people have found it more difficult to keep up with modern tendencies, and for this reason are now also on the whole a conservative class. In their day many of them, too, were pioneers, *e.g.* in accepting Christianity, but they have since been left behind, especially by the recent advances in education. But in the tribe as a whole, the differences now seen in regard to acceptance must be attributed mainly to the impetus derived from certain initial innovations.

Thus, one line of difference is found between those who have been educated and those who have not. It is only within the last fifteen years or so that education has really gone ahead in the tribe, due largely to the efforts of Isang. But already certain results or rather tendencies are beginning to show themselves. Education is free, except for a small entrance fee and the cost of books; and it has been made more or less obligatory for parents to send to school all the children they can spare from cattle-herding and domestic duties. Many parents, however, complain a good deal at being deprived of the help of their children, and will take them out of school after only a year or two. Others realise the economic advantages of education, and encourage it as far as they can. On the average, about 20 per cent. of the children of suitable age actually attend school, the overwhelming majority being girls. A survey made of the ambitions developed among them showed that very few were anxious to pursue the customary occupations of their people. The great majority all aimed at a career with which they had been made familiar by the introduction of Western civilisation. The boys, *e.g.*, wished to become builders or carpenters, teachers, doctors or preachers, and the girls teachers, dressmakers or nurses. All the occupations mentioned are based upon their own experience inside the Reserve of the heights to which their people have attained or can attain. This accounts for the rather curious range of choice. Few are ever likely to realise these ambitions, but the preferences expressed are significant as an illustration of the new values created by contact with civilisation.

So far only a small number, not more than eighty at the most, have been

able to proceed to higher institutions of learning in the Union or Southern Rhodesia. They have qualified mainly as teachers or artisans. The majority have afterwards had to seek employment outside the Reserve, owing to the lack of sufficient openings at home. The tribe has thus lost young men and women who should have been potential leaders to progress. Those employed in the Reserve, especially as teachers, enjoy considerable prestige, both because of their superior education and because they are relatively well paid; and they have exercised a tremendous influence upon the children under their care. They have tended more readily than any other section of the community to discard old tribal practices and embrace the ways of the white man. They regard it as quite fashionable to speak English even among themselves; they show a preference for European foodstuffs and such relatively novel articles of clothing as pyjamas or bloomers; they have taken up ballroom dancing, to the music of the gramophone; they have begun to practise kissing as a part of love technique, to employ European contraceptives, and even to read the works of Marie Stopes and kindred authors! All these are quite recent innovations, dating back not more than three or four years, and have caused much concern to the older members of the tribe. These youths, on the other hand, complain bitterly at the lack of the social amenities to which they became accustomed in their training institutions, and many are anxious to break away from the tribe and seek more "civilised" surroundings. In the meantime they appear to find a fairly congenial outlet for their unrest in sexual intrigues, in which they indulge very freely, with occasionally unfortunate consequences for their pupils and other girls.

Another line of division is becoming apparent between the sexes. The men have on the whole been more exposed to European influences, mainly as a result of labour migration. In the towns they experience the relative freedom of a different culture, in which their domestic sanctions no longer affect them directly, where the laws and tabus of tribal life may be broken with relative impunity, and where the authority of the chief is replaced by that of the employer and the policeman. They have accordingly tended more readily than the women to discard old tribal practices. But in one respect the women have taken to Western civilisation far more extensively than the men. The great majority of Church members are women. Indeed, the lack of male support is causing the Mission authorities grave anxiety. But as the men must go abroad to work they are unable, even if they wished to do so, regularly to attend catechism classes for the two years which the Mission demands as a preliminary to confirmation and acceptance into the Church. The women, moreover, remain at home all the year round, and to them the Church and all its doings provides a more welcome diversion from everyday doings than it does to the men. So, too, girls greatly out-

number the boys at school, because most of the latter are compelled to spend the greater part of their youth at the cattle-posts, which are far removed from the villages and so from all possibility of education.

Wealth also has determined to some extent the adoption of European traits. Most members of the tribe would like to purchase the more expensive goods stocked by the traders, to own wagons, good ploughs and European furniture, and to erect houses after the European style. But only the richer people can afford to do so. Consequently, it is principally among them that extensive material change of this kind is found. The chiefs and their relatives, in particular, have taken the lead in this direction, and have even acquired motor-cars and similar luxuries in which their greater wealth enables them to indulge.

A further distinction is found between members of the Church and what may best be described as the "nonconformists." Although Christianity is the official religion of the tribe, by no means all the people are members of the Church. Lentswe's acceptance of Christianity prevented that marked rift between these two classes which plays so prominent a part in the life of some other less fortunate South African tribes. But certain differences nevertheless exist. The Church members not only have their worship to distinguish them. They must also conform to the social and moral ideals preached by the Mission, dress in a "respectable" manner, and abstain from certain tribal customs regarded as incompatible with true Christianity. They do not always live up to these standards, which nevertheless constitute a recognised line of demarcation between them and the rest of the tribe. The latter, as would be expected, have on the whole more openly retained the beliefs and practices ostensibly abandoned by Church members. But in other directions there is little to choose between them, and indeed among the "nonconformists" are found some of the "most progressive" men of the tribe.

Resistance and Rejection.

Not all the traits of civilisation presented to the BaKxatla by the Europeans have been incorporated into the tribal culture, nor has equal progress been made by those that have been accepted. In some cases, too, the BaKxatla have resisted attempts made by the Europeans to change tribal institutions, practices and beliefs. We have to deal here with what may be termed the phenomena of resistance and rejection, and to determine why the response in this connection has been less favourable towards civilisation than it has been in the instances noted above.

It has already been shown how in the middle stage of contact Lentswe opposed the construction of telegraph and railway lines through the Reserve, fearing they would hasten the fatal impact of Western civilisation. Even

after his policy had changed, he and later Isang continued to exercise care in the admission of new influences. Thus, labour recruiters for the mines are not permitted to operate in the Reserve. This is due primarily to the fact that some BaKxatla were once accidentally killed on the mines. But it is due also to the hope of the chiefs that their men will engage in work more likely to be of use to them after their return, *e.g.* in agriculture and the building of roads. No pressure, however, is put on men to prevent them from going to the mines, and quite a large number do so of their own accord. The chiefs also forbade the entry of Indian traders and "poor whites" into the Reserve, and the introduction of European liquor. So, too, Lentswe refused to permit other denominations to establish Missions in the Reserve once he had given his adhesion to the Dutch Reformed Church. In all these instances a deliberate policy was followed of excluding undesirable influences or potential sources of internal conflict. But examples of this nature are comparatively few, and for the most part the process of resistance has taken place in regard to features already introduced to the tribe.

In economic life, for instance, we find that in contrast to the widespread and rapid adoption of European material products relatively slight progress has been made in subsistence activities. Many people have acquired a taste for such European foodstuffs as sugar and tea. But for their staple food supply the BaKxatla still rely almost entirely upon their former activities of cultivating crops, animal husbandry and hunting. Hunting has in one respect become easier now that many men possess guns. On the other hand, most of the game in the vicinity of the villages has been killed off or scared away, with the result that this important source of fresh meat has really become more difficult to exploit. Methods of cultivation were somewhat improved by service with the Dutch farmers in the Transvaal, from whom the BaKxatla learned the use of the plough. But this initial gain has not been followed up. The ploughing is badly done, neither manuring nor rotation of crops is practised, no new crops have been brought under cultivation, and little effort has been made to introduce seed of better quality. Similarly, there has been little change for the better in animal husbandry. The BaKxatla attach considerable importance to their cattle, which are not only used to provide food in the form of meat and milk, but serve also as mediums of exchange and ritual killing. A man's wealth is estimated by the size of his herds, and it is the ambition of everyone to have as many cattle as possible. Consequently far more value is still attached to the number of cattle than to their quality. This in turn leads to overstocking and over-grazing, with their consequent evils of soil erosion and further deterioration of the cattle.

This retardation must be explained partly by the fact that for a long

time the BaKxatla herded cattle and raised crops for their own subsistence only. No efforts were therefore made by either the Administration or the chiefs to improve farming methods, while the people themselves, apart from a few more enlightened individuals, were content with things as they were. But as new wants and obligations increased, it became obvious that local produce, and especially cattle, would be an important source of income. Veterinary services were then introduced by the Administration, Isang developed new water-supplies and preached better farming methods, and finally an agricultural demonstrator was appointed and attempts made to develop dairy industries. All this, however, is fairly recent, some of it dating back not more than four or five years, so that the results are still difficult to perceive. Retardation is aided by certain other factors. The old "communal system" of land tenure still flourishes unchanged, apart from a minor modification by the chiefs in granting limited individual rights to people digging wells for watering cattle. There has been no tendency at all towards the creation of private freehold allotments, similar to those established in the Cape under the famous Glen Grey Act of 1894. Consequently there has been no inducement to the people to develop their land. Labour migration, now relied upon as the main source of income, is acting at the same time as a brake on agricultural progress. The men during their absence at work leave the cattle-posts in charge of boys, with no adequate supervision. Herding generally has therefore tended to deteriorate, and less care is taken of the cattle than before. Some men, too, fail to return in time for the ploughing, which consequently has to be done by their wives and children, with equally unfortunate effects upon the quantity of harvest.

Similar instances of slowness in change can be found in social and political organisation. The tribe is of course no longer politically independent, and in all its external relations is subject to the direct control of the Protectorate Administration. But it has been allowed to retain its own form of government, and there has been little interference with the traditional system of councils.* The relations between the chief and his people have been somewhat altered, in a manner that will be dealt with below. But he is still their ruler, and continues to exercise many of his former powers and privileges, although his ritual functions have been largely displaced by Christianity. Almost all the lawsuits are still heard by the traditional tribal courts. These bodies are no longer allowed to impose the death penalty or deal with certain classes of offence which have

* At the end of 1934 two Proclamations were issued greatly modifying the tribal system of government and jurisdiction. As these have only just come into force, since the writer's last visit to the tribe, they have not been taken into consideration in this account.

been reserved for the jurisdiction of the European authorities; but on the whole they retain to a considerable degree their old methods of procedure and forms of penal sanction. Since 1919 there has also existed a right of appeal from the verdict of the chief and his court to the local European magistrate. This, however, seems to have been but seldom exercised.

The old grouping into *dikxôrô* (lineage groups) remains quite intact, although less importance is attached to their order of precedence now that most of the public ceremonies in which it was manifested have disappeared. The regimental organisation still flourishes strongly, and the regiments still retain their old function of performing various kinds of labour for the chief or on behalf of the tribe as a whole. But the preliminary initiation ceremonies (*boxwêra* and *bojale*) were abolished by Lentswe soon after he became a Christian. The tribe accepted this change with reluctance, and on several occasions men have gone to be circumcised at the corresponding ceremonies of neighbouring tribes, only to be punished by the chief on their return. Here again we meet with a marked instance of resistance to change, which has resulted, as will be shown below, in the development of a new form of initiation ceremony.

The character of the family, as will also be shown below, has been somewhat altered by the decay of polygamy and the weakening authority of the parents. But in the main changes have not been pronounced. The ritual associated with birth, marriage and death is still based upon traditional practice, even although various old usages have been discarded and additional elements incorporated from Christianity. The usages relating to sex have altered but slightly, and the old physiological ideas and tabus appear to be retained even by those who have received some education. The laws of succession and inheritance remain pretty much the same. The observance of kinship obligations and practices has been somewhat modified by modern individualistic tendencies; but the kinship system itself, based on the classificatory principle, has suffered little decay, and kinship bonds still play a conspicuous part in economic and ceremonial arrangements.

In both social and political organisation the relative slightness of change may be ascribed in the main to the absence of much direct attack upon their solidarity. The Administration, as we have seen, made a few necessary changes, but otherwise followed the policy of preserving and utilising as far as possible native laws and institutions. None of the other European influences impinged directly upon these aspects of Kxatla life, apart from the Mission. This agency attempted, as part of its general aim of evangelising and "civilising" the tribe, to discourage and even condemn certain practices. It met with some measure of success, but in several instances

the tribe resisted the change attempted, and the Mission policy had to be abandoned.

A conspicuous example of such abandonment was in the case of the *boxadi* practice, by which at marriage the family of the boy transferred some cattle as bride-wealth to the family of the girl. The early missionaries regarded this transfer as a form of wife purchase. Lentswe after he became a Christian was therefore persuaded to abolish it. It was soon found that this led to dissatisfaction and confusion. Isang when he became regent managed to impress upon the Church authorities that the absence of *boxadi* payments was tending to make marriages unstable. They accordingly agreed, after considerable discussion, to the restoration of the practice; and nowadays no marriage can be celebrated in church until the *boxadi* has been transferred. The same lack of success attended the Mission's efforts in other directions. It attempted, *e.g.*, to prevent marriages between Church members and "heathens," threatened to expel from the Church any member resorting to a native magician, and forbade converts to attend "heathen" ceremonies, even when relatives or friends were being married or buried. In all these instances it met with active opposition or passive resistance, and these laws are no longer in vogue.

Isang's attitude in regard to *boxadi* was part of a general attempt he made to retain, and where necessary revive, what he regarded as "good old" native customs which were falling into decay. At the annual thanksgiving services to commemorate the migration from the Transvaal he would ask the old people to address the assembled tribe on their traditional history and customs. He encouraged the people to speak pure SeKxatla, for the language is becoming corrupted by the intrusion of Afrikaans and other European words. He insisted upon the proper celebration of marriages, and revived the ritual purification of people who had suffered bereavement. Above all, he openly restored the old rain-making ritual, mainly as the result of pressure from the tribe, but partly also because he realised that it would give him a firmer hold upon the people, who have not yet lost their conviction that the provision of rain is one of the main duties of the chief. His object in all this, he maintains, was to develop among the people a feeling of patriotism, of pride in their own culture, in so far as it was not blatantly in conflict with general social and material advancement. The encouragement he thus gave to the retention of old practices and beliefs served of course as a powerful check against their disintegration.

The greatest failure of the Church, and of Western civilisation generally, has been in regard to magic and sorcery. The practice of magic still persists strongly, even among members of the Church. Many a man who has long abandoned ancestor-worship in favour of the Gospel, or perhaps has never even known the old tribal cult, yet feels it necessary to have himself and

his family, his huts, his cattle and his gardens regularly charmed. The belief in sorcery is still vigorous. There is nothing the native fears more than being bewitched, and should any misfortune befall him he will attribute it to sorcery rather than to the hand of God. The Administration will no longer tolerate the killing of sorcerers, and has made it a penal offence even to accuse people of sorcery. Consequently alleged sorcerers are no longer dealt with in the tribal courts, although cases are quoted, always in strict confidence, where they have been secretly destroyed or severely injured with the connivance and indeed active participation of the chief. Even where they are not directly punished, their living presence is a disturbing factor in social life and the cause of much ill-feeling and malicious gossip; and there has been a marked development of magical methods of avenging their nefarious activities.

It is difficult to account for the persistence of these beliefs and practices in contrast with the almost complete disappearance of ancestor-worship. In part at least it may be due to the continued existence of the professional magicians, who have not been prevented in any way from carrying on their work. The chiefs themselves, although ostensibly Christians, firmly believe in magic; and Isang, as just stated, insisted upon the performance of certain rites involving the participation of magicians. Lentswe himself, despite his otherwise enthusiastic acceptance of Christianity, regarded it as his duty to the tribe to continue making rain, albeit secretly. His successors have followed his example, somewhat more openly, and have thus set a lead which the tribe generally has been happy to follow. But in the main it would seem to be due to the fact that magic plays a part in tribal life which none of the new influences has so far been able to fill. It enters intimately into all their everyday activities and occupations, providing them with a hope and confidence which enables them to tide successfully over difficulties and disappointments. Christianity is for the average tribesman too remote from the realities of economic and domestic life to provide an acceptable substitute, while modern scientific teaching is too recent an innovation and too limited in its extension to have been able to make much headway against the traditional system of ideas underlying the belief in the efficacy of magic.

A good illustration of this last point is seen in regard to the European medical services, which have only recently been introduced. For most cases of illness the people still prefer their own treatments and practitioners, and generally they will call in the Mission doctor only when every other hope has failed. But they are tending more and more to resort to him for minor casualties and ailments, as well as for really grave illnesses. Even magicians have on occasion been known to prefer the attentions of the Mission doctor to those of their own colleagues. The general superiority

of modern medical science to the practices of native healers is slowly being realised, and the prospect of greater, even if very gradual, progress in this respect is not altogether as discouraging as Europeans sometimes seem to believe.

It must finally be noted that misunderstanding of innovations and suspicion of the motives behind their introduction have all along contributed towards resistance to change. In the early days it was sometimes alleged by the people that the church bells of the missionaries were driving away the rain. Taxation and the payment of Church dues are regarded by some as means of enriching the Europeans by false methods and empty promises. The recent inoculation of all cattle in the Reserve to prevent the entry of foot and mouth disease was interpreted as a sly device to kill off all the beasts, and the erection of a cordon fence to confine the cattle within a clean area was thought to be an equally sly method of stealing tribal land. There is a genuine dread that one day the Reserve may be taken away from its inhabitants, and this colours to a great extent the popular attitude towards some attempts at economic advancement. The Mission hospital, again, when it was first opened was received with sullen hostility by some of the people, who saw in it a place where their sick would be brought only to die under the knife. There thus appears to be as great a need for the native to be taught something about the culture of the Europeans as there is for the white South Africans to understand the life of their native fellow-countrymen. In the meantime ignorance on the part of the native breeds in him suspicion of the European, and where there is suspicion there is always resistance to change.

Displacement and Adjustment.

We may now turn to consider the disappearance or decay of traditional native traits as a result of contact with civilisation. Displacement of this kind may in general be attributed to two main causes: (*a*) The policy adopted by European authorities in regard to the tribal culture, and (*b*) the effect of innovations. It has already been shown that both the Administration and the Mission regarded various Kxatla practices and institutions as undesirable or offensive, and tried to abolish or modify them. So, too, many of the innovations that were accepted brought in their train the elimination of traditional cultural manifestations. In several other instances there has come about what may best be described as a process of adjustment or substitution, where an old trait has been modified or replaced through the taking over of new traits. We meet with a similar phenomenon in regard to some traits acquired from Western civilisation, which have been modified and reinterpreted so as to blend more harmoniously into the aspects of tribal life they have affected.

Modifications of Indigenous Traits.—We may notice first a relatively simple series of instances of substitution. The acceptance of the material objects introduced by the Europeans has led to the decay of old industries. The art of smelting iron and making iron implements and utensils, formerly in the hands of special craftsmen, has disappeared completely. Metal goods are now obtained solely from the traders. One native smith within fairly recent times managed to acquire the new techniques involved in such work as repairing wagons and ploughs, and to practise them. But since his death such work has been done exclusively by European blacksmiths, except for minor repairs done by the people themselves. The leather industry, through which the men provided the clothes of the family and made such objects as shields, bags, milk-sacks, mats and karosses, has become far less important now that blankets, clothes and dress material are obtained from the stores, and milk-sacks can be made from canvas. Pottery, basketry and woodwork, although still practised to a certain extent, are becoming more restricted in their practice and scope. Iron cooking-pots and empty petrol tins are replacing the more fragile cooking and water-pots of clay; enamel basins and plates are used by many instead of the old baskets and wooden eating-bowls, and metal buckets are preferred to wooden milk-pails. Good specimens of old native crafts are becoming increasingly difficult to obtain, and some are no longer obtainable at all, *e.g.* shields and certain kinds of ornament. To a limited extent also rectangular dwellings are replacing the old circular huts. Most of these new dwellings are built, like the old huts, with earthen walls and thatched roofs, but wealthier people have brick houses with corrugated iron roofs.

The introduction of the plough led to various modifications. In the olden days it was tabu for women to have anything to do with the cattle. They neither herded them nor milked them. When the plough was introduced, and it became necessary to harness the oxen, the men for the first time began to take a more active part in the agricultural routine, not only because of the greater labour involved, but also because women were still debarred from handling the cattle. Conditions have since changed to such an extent that this old tabu no longer operates among the BaKxatla. Women, save for certain restrictions associated with ritual impurity, are no longer prevented from working with cattle. It is quite common, at the beginning of the agricultural season, to see a woman behind the plough, or leading the oxen while her husband guides the plough. Here we have an excellent illustration of the way in which the acceptance of a new trait led to a fairly profound modification of tribal life before it could be fully incorporated. The harnessing of oxen to the plough and to the wagon was in itself a new use for cattle. In its train it brought the development of

new crafts, such as the manufacture of wooden yokes and leather harness, and the training of oxen to serve as draught animals.

In family life we find not only the decay of polygyny, to which further reference will be made shortly, but also the almost complete disappearance of such institutions as the levirate and sororate. Church members are forbidden to practise them, but even among "nonconformists" they have been largely abandoned, and will no longer be enforced in the tribal courts. The disappearance of ancestor-worship has deprived the family head of his old function of domestic priest, formerly a strong bond of family solidarity. Other forms of domestic ritual, particularly the ceremonies connected with birth, marriage and death, have lost some of their old features. Many incidental rites were described as having been formerly practised, but instances of their survival were difficult to find. Infant betrothal was a common practice in olden days, but it has now almost entirely died out. The old rite of *xo apara lemipi*, by which at marriage the fatty membranes of a slaughtered ox were hung round the necks of bride and bridegroom, has long ago been discarded, as out of place in a ceremony where the main participants are dressed in a new outfit of European finery. In former times men were buried in their cattle kraals, in a sitting posture and wrapped in the skin of a newly-killed ox, while women were buried in the yards of their household enclosures. Nowadays all adults are buried, lying in wooden coffins, in special cemeteries on the outskirts of the villages. But the traditional mourning observances still survive.

The relation between parents and children has also undergone a good deal of change. In the olden days children were wholly subject to their parents, and unquestioning obedience in everything was demanded from them. The young people were instructed within their household group in the economic activities of their tribe, and both here and later at the initiation ceremonies they received a character training which with all its defects was nevertheless an efficient agency in making them conform to the needs and standards of their people. Civilisation has destroyed some of this old educational mechanism, and substituted for it the School and the Church. In neither of these institutions does the native child receive the same comprehensive upbringing that was, and to some extent still is, provided in the home. On the other hand, the weakening of parental authority has diminished the efficiency of the domestic system of training. This is particularly so in the case of school children. Not only does the periodical migration of their fathers to the towns in search of work free them from the presence of paternal authority, a freedom which they share with other children; but for part of the year, while the people are living at their gardens, the school children remain more or less by themselves in

the villages where they go to school. There has consequently been a development of youthful independence and irresponsibility which the old forms of authority are no longer able to control, and which the new influences seem unable to check. The young people no longer look to their parents for guidance in everything, but are tending more and more to do as they please.

This is reflected in the changed attitude towards premarital births. In the olden days an unmarried girl who became pregnant was an object of universal scorn and suffered numerous public humiliations. Her child was often enough killed at birth, or if allowed to live always laboured under a marked social stigma. Nowadays the girl is treated at most with a mild contempt which soon dies away, while illegitimate children, although subject to certain disabilities in the matter of inheritance and succession, are allowed to take full part in the normal tribal life. This new attitude is the product of several different causes. Among these may be listed labour migration, which among other things has led to a shortage of young men in the Reserve; the abolition of the old initiation ceremonies, which constituted a powerful disciplinary force; the spread of education, which has given the younger people a greater sense of freedom; and the Mission ban against polygyny, which has deprived some women at least of the prospects of early marriage. For all these reasons, premarital sex relations have become almost a matter of course, and pregnancies far more numerous than formerly.*

Labour migration has led also to other changes in social life. Most of the men when they come back from work seem to settle down again quietly to the routine tribal life, especially if they are altogether illiterate. But others, above all those who have been away more than once, are somewhat dissatisfied in mind and out of love with the old order of things. There is as yet no marked tendency towards open revolt against tribal life, but many symptoms of disaffection are visible. This is especially true of the younger unmarried men who are nominally still under the control of their fathers. They soon become impatient of the traditional authority exercised by the latter, object to interference with their freedom of movement, and may even be openly insolent to their elders. They will no longer let their parents arrange their marriages, but choose their own brides. This sometimes leads to violent family quarrels and consequent bitter accusations of sorcery. In a few cases they have even after marriage gone to live permanently at the home of the wife's people, a procedure altogether opposed to traditional Kxatla usage.

In political life similar changes can be seen. On the one hand, the chief has tended to become more and more autocratic. Freed by the strong

* This topic has been dealt with more fully in a paper on "Premarital Pregnancy and Native Opinion: a Note on Social Change," *Africa*, vol. vi (1933), pp. 59-89.

support of the Administration from fear of the tribal sanctions which formerly restrained him, he has become more arbitrary in action and more jealous of any challenge to his authority. On the other hand, the people are becoming increasingly critical of the chief as a person, although loyalty to the chieftainship as an institution does not seem to have been much affected. It is alleged that the present chief's irresponsibility and lack of concern for his tribesmen are causing many to stay away longer at work than they would normally have done. Those who do come back strongly resent the frequent demands he makes upon their services. This is particularly so in regard to the big tribal undertakings which the regiments are called upon to perform. A call of this sort now almost invariably raises the complaint that they are forced to do such work for nothing instead of being paid for it, a complaint based on the knowledge that by going into the Transvaal they can generally manage to obtain remunerative employment.

The introduction of Christianity, to take another example, has led to an almost complete abandonment of the old tribal religion. Hardly any of the younger people know what is meant by the ancestral spirits, and even among the older people there is now nothing in the form of a positive cult outside Christianity. Those who are not members of the Church hold vague beliefs largely derived from echoes of missionary teaching blended confusedly with memories of ancestor-worship, but they have themselves no formal system of worship. The Christian conception of God has so effectively replaced the old native conception of the personified deity *Modimo* that it is impossible to obtain a clear account of the latter and his attributes. Similarly, the religious and magical functions of the chief have been largely displaced since the introduction of Christianity; and although the people still look to him for rain he no longer plays an outstanding part in their ritual life. Lentswe after he became a Christian deliberately ceased practising some of the major tribal rites, such as the feast of the first fruits, the ceremonial charming of the country, and the harvest festival; and since they could not be celebrated save under his authority and with his participation they have altogether died out. The old people lament the passing of these ceremonies, and maintain that many of the modern ills of the tribe are due to their abandonment. The old war ritual, and indeed the whole complex of usages relating to war, have also disappeared, since the Administration took away from the chiefs the right to make war. On the other hand, certain new forms of magic have been developed to cope with modern conditions. There is magic to ensure success in looking for work, and magic to increase the efficiency of ploughs, guns and traps; and there is even magic to soften the heart of the trader and make him reduce his prices.

Religion provides a good illustration of the substitution of one culture trait for another. An equally good illustration of modification or adjustment is provided by initiation. In the olden days, all children of the same sex and about the same age were ceremonially initiated into membership of a regiment (*mophatô*). The boys' ceremony (*boxwêra*) involved a period of seclusion from the rest of the community, during which the initiates were first circumcised in order of tribal precedence, and then systematically taught a number of secret formulae and songs, the tribal laws and beliefs, and the necessity of implicit obedience to their elders. They were also subjected to hardships of various kinds. The details of the ceremony were kept a profound secret from all non-initiates, and violation of this secrecy was punishable by death. These rites the early missionaries regarded as most immoral; and when Lentswe became a Christian he was persuaded to abolish them. But he retained the system of regimental organisation. For a time no preliminary rites at all were held, with the result that some of the boys due for incorporation into a regiment went to the *boxwêra* ceremonies of neighbouring tribes. The tribe as a whole, too, began to protest that members of new regiments should receive at least some sort of instruction in behaviour and learn their order of precedence. Accordingly, a modified system of initiation has gradually grown up again. The boys are now still isolated for a time, during which they receive the necessary instruction and are subjected to strenuous hunting tests. But the old circumcision ceremony, with its accompanying mystery and lore, has been completely abandoned, the element of secrecy is no longer stressed, it is even no longer regarded as essential for every boy to pass through the rites before being accepted into a regiment. The final phase, in which the initiates are welcomed back into the community, was even made in part, at the most recent initiation, held in 1928, the occasion of a Church ceremony. The girls' ceremony (*bojale*) was formerly also an elaborate affair, involving many secret rites; but nowadays it consists merely in a week's dancing and singing at night, followed by a public gathering when the chief gives the new regiment its name.

A similar process of adjustment is seen in regard to polygyny. The missionaries from the first opposed this practice, and no Church member is allowed to have more than one wife. The Administration also imposed an additional tax upon all polygynists. There has in consequence been a marked decline of the institution. Less than 5 per cent. of the men now have more than one wife, and the number with three or more is exceedingly small. The result has been the greater spread of concubinage, coupled with the wider application of a subsidiary native institution. In certain cases, where a man is too poor to pay *boxadi* (bride-wealth) or for some other reason none has been transferred, the marriage can be established

and the children fully legitimised to their father by a system of "postponed *boxadi*," *i.e.* the *boxadi* of the first daughter goes, not to her father, but to her mother's people, and the mother is then said to be "caused to be married." All other children only then become the legitimate children of the couple. Many men now have concubines where they would formerly have had additional wives. No *boxadi* is paid for these women, nor is any ceremony performed. Hence the additional tax is escaped and the censure of the Church avoided. The relationship between the man and his concubine is considered regular, since her parents approve; but it only becomes a marriage in fact and the children legitimate when the *boxadi* of the eldest daughter is transferred to the woman's parents.*

Modification of Borrowed Traits.—Many of the traits taken over from Western civilisation have been given a new meaning in Kxatla society, or put to new uses. A few minor illustrations may first be taken from material culture. Ordinary table-knives, with their blades ground fine, are often used for carving wood and working in leather; the large drums in which the traders receive their stocks of petrol are bought by the natives for transporting water; beds are rarely slept upon, but cherished rather as symbols of wealth and progress; vaseline to some extent fills the place of the old ointments for making the skin shine; salt, like the indigenous beer, is used also as payment for certain kinds of work; umbrellas are used mainly as sunshades; while ink mixed with the pulverised heads of matches is a common abortifacient!

More delightful instances of adjustment are found in marriage customs. The Church wedding has been grafted on to the old marriage ceremonies, and now forms the first stage, followed by the traditional festivities at the homes of both parties. The Church will marry people only on Thursdays, and it has become the rule even for "nonconformists," who of course do not get married in church, to begin their marriage celebrations on this day. The traditional seclusion of the bride for some time immediately before she is married now commences, in the case of Church members, from the day the banns are first read. Bridal veils and white wedding garments may be worn only by women married for the first time, whether in church or not. Widows and divorcees who are marrying again, and girls who are already mothers by the time they are married, are held to be unworthy of this special distinction. Cross-cousins played an important part in the old marriage festivities, and even to-day the "groomsmen" and "maids of honour" are usually drawn from their ranks. There is in all this a

* Cf. for fuller details the paper on "Premarital Pregnancy and Native Opinion," already cited. The wording in the latter half of this paragraph is taken almost literally from a convenient summary by Mrs. A. W. Hoernlé, *South African Journal of Science*, vol. xxx (1933), p. 84.

well-marked assimilation of new elements to the old basic usages which still persist.

An interesting problem arose in connection with the Church marriage. To the natives this is primarily a religious affair. But since the missionary is an official marriage officer of the Protectorate they bring themselves, by the Church marriage, under the operation of Protectorate civil law. This meant that in cases of dispute, leading to divorce, the custody of children and property rights would be dealt with in a manner altogether alien to tribal usage. The people, when they realised this, became increasingly reluctant to go to the magistrate, and persisted in bringing their disputes to the chief. Isang pointed out to the Administration the difficulties this involved in the matter of relative jurisdiction. As a result the Protectorate law regarding native marriage was amended. At the present time, while cases of divorce between people married in church must still come before the magistrate, if any question of property is involved this may then be handed over to the chief for settlement.

Certain Christian doctrines and practices have also been modified in the course of acceptance. The Church day of prayer for rain is regarded by many as part of the rain-making ritual in general, and the teaching that God sends the rain is interpreted even by orthodox believers to mean that He sends it through the chief. The observance of Sunday as a day of rest has added another major tabu to tribal life, and the consequences of violation are often held to be similar to those attaching to violation of ancient tribal tabus. Some magicians assert in all good faith that their craft was originated by Adam, who was thus not only the first man but also the first magician. From the Boers in the Transvaal the BaKxatla have taken over the belief in "spooks": but with certain qualifications. Most of them believe that dead people go either to heaven or hell, according to their life on earth; but those too bad to go to hell, or still hankering after the wealth they left behind when they died, become ghosts or "spooks" hovering around the world of the living.

Christianity itself as practised by the BaKxatla is not the Christianity for which the Mission had hoped. The sweeping victory of the missionaries has led to religious stagnation. Only about one-third of the adults in the tribe are full members of the Church. To most of these their religion is merely conventional. Attendance at church and at prayer meetings has become largely a matter of routine or at best provides a mild diversion from everyday activities. To the younger generation the church is mainly a place where they can parade in their best clothes and impress the opposite sex. Very few of the people thoroughly understand the principles of Christianity. Not many are sincere in their professions of faith or strive to lead a true Christian life, while well-founded accusations of

hypocrisy are by no means infrequent, and cases of backsliding are also encountered.

The explanation for all this is found partly in the monopoly given by Lentswe to the Dutch Reformed Church in the Reserve. This has deprived it of the stimulus that might have been derived from competition. Again, the conversion of the Mission into a tribal Church has led to the acceptance of Christianity as a matter of course rather than persuasion or conviction. Another powerful factor has been the personality of the Church leaders. The native elders and evangelists are criticised freely as overbearing, autocratic, hypocritical, and partial in their administration of the Church laws. The missionaries themselves have, with few exceptions, seldom been able to win the confidence and trust of the people, nor have the lives they led always reflected the moral ideals they preached. On several occasions unfavourable criticism of the missionaries developed to such an extent that it was only with difficulty, and after the intervention of the Central Mission authorities in Cape Town, that more friendly relations between them and the tribe could be restored.

In a desperate attempt to regain the ground it has lost, the Mission has recently changed its policy towards the old tribal culture. The new tendency, according to its local representative, "has been to give the tribe a form of national religion, based on the principles of Christianity, but adjusted as far as possible to Kxatla beliefs and aspirations. *Boxadi, e.g.*, is now recognised as an essential part of Christian marriage; the initiation ceremonies for boys are no longer frowned upon, but an attempt is made to direct and control them; * and national Church festivals have been instituted." This new policy is in part due to a general change in the trend of modern Mission policy. But in part it is certainly also the result of experiences among the tribe, and as such it affords another illustration of the way in which new traits have had to be modified in order to prove acceptable to the people.

We may finally note, as still another illustration of adjustment, the way in which the prestige of the white man has altered as a result of further intercourse. The day has passed when he was regarded as a being of a superior order. The Europeans with whom the BaKxatla have come into contact at home have not on the whole left a favourable impression. The comments passed on some missionaries, traders and Government officials as individuals reveal an unmistakable sense of bitterness and underlying contempt. This attitude has been much strengthened by the experiences of those working abroad. The white man's civilisation, and particularly its material manifestations, at first move the native to deep

* For the extent of this "direction and control" *cf.* the account given above (p. 246) of the modern initiation ceremonies.

astonishment and awe. He regards the Europeans as "next to God in wisdom and knowledge," and hails his technical achievements as feats of supernatural endowment. But as time goes on the effect wears off; and although the native still does not understand how some of these things are produced, he comes to take them for granted as a desirable part of the white man's civilisation, and tries to acquire for himself what he can of it. On the other hand, his own treatment and experiences at the hands of the European leave effects by no means so reassuring or flattering. He contrasts very unfavourably the low wages he receives with the apparent wealth surrounding him on all sides; his glimpses of European social and domestic life, so different from his own, arouse his contempt more often than his admiration; and if a Christian he notices that the Sabbath is more honoured in the breach than in the observance. Some of them even come to believe that Christianity is a religion specially invented by the Europeans to be foisted upon the native, a belief that of course also affects their attitude towards Christianity in the tribe. Above all, they resent very much the differential treatment represented in the social and economic colour bars, and are moved to fury and hate, none the less dangerous because superficially impotent, by the pass system and by the occasional brutality of the police and other Europeans. The dominant impression with which most of them return to the Reserve is that the Europeans wish to keep them in a state of abject servitude for all time; and although they do not appear as yet to harbour any thoughts of active revolt, their feelings against Europeans in general are on the whole far from friendly.

The Results of Acculturation.

In the light of the foregoing analysis we may now attempt to estimate generally the present cultural condition of the BaKxatla. The dominant impression left upon the student in the field, who is able to observe intimately and to some extent participate in the life of the people, is that they have so far on the whole adapted themselves with considerable success to the impact of Western civilisation. The BaKxatla have not become "detribalised" in the same way as have so many natives of the Union, nor have any changes yet taken place in the structure of Kxatla society comparable to those which have differentiated the natives of the Union into several distinct classes. Their culture at the present time is not the traditional Bantu culture of the Tswana tribes, nor is it the civilisation of the European inhabitants of South Africa. It includes elements of both: but they have been combined into a new and distinctive pattern. The native living under this new form of culture is no longer conscious of a sharp breach between Kxatla and European elements, as were his grandfather and even his

father. It is true that the few Europeans in the Reserve differ from him in skin colour, mode of life and cultural allegiance. But the institutions they represent are now fully part of the tribal culture. Christianity is the tribal religion, the trading store is an essential part of modern economic life, and the Administration an integral part of the existing political system. The school is even more notably an established part of the routine educational system, in that all the teachers in the Reserve are themselves natives. All these new elements have been smoothly worked into the tribal culture, in some cases enriching it, in others replacing corresponding elements which formerly existed. The modern culture also displays far more numerous variations in detail than did the traditional one. But these variations, whether in marriage or in belief, in morals or in economic life, now exist within a single cultural whole, and no longer reflect two different cultures in juxtaposition. The tribe is still a solid unit, and its members do not feel themselves culturally divided.

In attempting to account for this successful measure of adaptation, we must once again emphasise the conditions under which the BaKxatla encountered Western civilisation. In the early years of contact they deliberately withdrew from intimate social and political intercourse with the Boers in the Transvaal, as they were then still able to do, and established themselves in Bechuanaland. Here they were able to meet civilisation on their own ground, in a tribal Reserve of ample size, within which no European may own land. The handful of resident Europeans who are the main front of Western civilisation represent a select series of influences. The Administration, potentially the most dangerous influence making for change, deliberately instituted and pursued a policy of preserving and utilising the tribal institutions, and thus considerably slowed down the rate of change. But, above all, for more than fifty years, during the time when Western civilisation was spreading through the whole of Bechuanaland, the destinies of the BaKxatla were guided by two chiefs of outstanding ability. To them more than to any other factor is due the success with which the tribe has withstood disintegration or at best demoralisation, and with which it has taken from the Europeans the elements most likely to help it cope with the new situation. Not all the Tswana tribes have been equally successful, but where conflict between the new and the old is still found or where tribal solidarity has suffered, incompetent chiefs have usually been largely responsible. Lentswe and Isang ruled their people strongly and wisely, so that even labour migration, almost invariably productive of harm, has worked far less havoc among the BaKxatla than it seems to have done in other parts of South Africa.

But the process of acculturation is as yet by no means complete. The great developments of the past fifteen years or so are part of a more intensive

pressure by Western civilisation which has only just begun. Even during the five years over which the writer has been studying the BaKxatla many changes have taken place; and all the signs indicate that in the near future will come a critical stage in the history of the BaKxatla and of all the other Protectorate tribes. In their reaction to it will lie the ultimate fate of their culture. What pattern it will finally assume is difficult to predict. In religion, education and certain aspects of economic life they are apparently tending to assimilate towards Western civilisation, while in social and political life they are developing along somewhat different lines. But how far these tendencies will be strengthened, and how far they will be diverted, by the new Administrative and Mission policies, not to mention the probability of "incorporation" into the Union, cannot be foretold until these policies have had time to make themselves felt.

PREHISTORIC ROCK ENGRAVINGS IN THE VAAL RIVER BASIN.

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(With Plate XI and three Text-figures.)

(Read June 17, 1936.)

Introduction.

One of the fruits of the recently completed archaeological and geological survey of the Harts, Vaal, and Riet River Valleys * was a most unusual opportunity to study the prehistoric rock engravings and peckings that abound within the area surveyed.

The total number of farms known to contain sites in the Vaal River basin alone is ninety-five, spread over an area of approximately 35,000 square miles of the S. and S.W. Transvaal, the W. Free State, and Griqualand West. On one farm there may be as many as half a dozen sites, and one site may contain hundreds of pecked or "engraved" figures, or it may contain only a few.

Miss Wilman's great work on "The Rock Engravings of Griqualand West" (1) emphasises the importance of the area. Attention was, however, first drawn to it by Holub, who trekked through it between the years 1872 and 1879 (2). Holub paid particular attention to the famous site at Gestoptefontein in the Lichtenburg district of the S.W. Transvaal, where he remained for a sufficient length of time to remove no less than 140 figures (3). These were transported to Vienna, where they were recently described and splendidly illustrated by Želizko (4).

Holub distinguished four series:

1. Oldest. Chipped (*eingehackt*) contours only.
2. Chiselled (*ausgemeisselt*) silhouettes.
3. Contours cut (*geschnitten*) or scratched (*geritzt*)—seldom finely cut; the inside always rubbed (*ausgeschliffen*).
4. Period of decay: figures merely cut out or poorly chiselled (*not* chipped). Contours.

Series 3 he describes as the best period.

* Nature, vol. cxxxvi, No. 3451, pp. 981 and 998–999. The final report on the results of this survey is in course of preparation.

It is difficult to understand how Holub arrived at this sequence when a study of the figures removed show cut or *engraved* lines (Holub's Series 3) consistently *under* all pecked figures, whether the latter are coarse, fine, in profile or in silhouette (Series 1 and 2).*

Burkitt was really the first to study "engravings" systematically (5). He was closely followed by Miss Wilman. Both recognised an artistic succession, and an evolution from crude beginnings to a fine or "classic" finish before modern man began his crude imitations and mutilation.

Each has four series. Miss Wilman's are noted as Classes and are subdivided as follows:—

Class I. This includes all the "classical engravings" in amygdalloidal diabase and is subdivided into three styles:

Style (i) Isolated pits or lines of pittings which not infrequently underlie

Style (ii) Engravings with pitted or grooved outlines, and

Style (iii) Engravings in which these outlines are dispensed with.

Class II. Imitations of Class I—also referred to as Style (iv).

Class III. "Spoors" (*cf.* p. 43, Wilman, *loc. cit.*).

Class IV. "Scribblings," modern metal tools often used.

It must be noted that Miss Wilman, who confined her work to Griqualand West, uses the word "engraving" to describe figures pecked or chipped out of the rock, but not necessarily incised with a graving tool or burin. The use of the word "engraving" to describe all these rock pictures has become general, and it is a remarkable fact that very few real engravings are known. The vast majority of the figures are pecked or chipped out of the rock with no semblance of incised (or engraved) work in the technique.

Burkitt has four series: the first and fourth include engravings; the second and third, figures that have been pecked or chipped out of the rock, or, as Burkitt puts it, "pocked" out:—

Series I. The engravings of this "earliest series show a fine incised outline, and the bodies of the animals are filled in with fine lines more or less parallel to this outline."

Series II. Comprises "figures of animals made by a pocking technique without any definite outline; sometimes there is merely an outline formed by a more or less wide band of coarse pockings."

Series III. Where the figures "are made by a fine pocking, so fine indeed that it is almost as though the surface of the figure had been rubbed over with sand-paper."

Series IV. Modern—apparently done with a metal knife.

* Želizko, *loc. cit.*, pl. i, fig. 1; pl. ii, fig. 2; pls. iii, x, xi, etc.

For reasons given in detail—patination in one case, superposition in another, and so on—Burkitt regards the series as chronological. Of this there can be no doubt; but recent work has shown that both Burkitt's Series I and Miss Wilman's Class I are incomplete.

Recent Research.

During the recent survey scores of sites containing rock engravings and pitted figures chipped or pecked out of the rock were examined, and in many widely separated cases we found finely incised lines forming simple geometric patterns (criss-crosses, triangles, squares, ladders, and variations of these) always finely *engraved* with a graving tool *under* the chipped-out figures of Miss Wilman's Class I and Burkitt's Series II, but similar to Burkitt's Series I. Both Miss Wilman and Burkitt note simply incised lines, but with these we recently discovered the figures reproduced in figs. 1, 2, and 3. These conform to the earliest style noted by me in 1929 (6), and resemble certain engravings of the Aurignacian * and Solutrean † rather than the later Magdalenian.

In fig. 1 are shown three types of *engraved* figures, all undoubtedly incised in the rock with a graving tool or burin of sorts. We have:

A. The simple geometrical figures referred to above.

B. Remains of engraved animals, etc., in profile only.

C. Portion of a fully filled-in engraving of an antelope, *i.e.* an engraving in silhouette. Nowhere are the lines more than a millimetre thick.

Similar engravings consistently *underlie* the pecked or chipped-out figures—especially at Gestoptefontein, where many instances of superposition may be seen.

In fig. 2 we see all that is left of a buffalo very finely engraved—also from Gestoptefontein. The lines are difficult to see, but photographs and rubbings were taken and reveal these under both finely and coarsely pecked or chipped-out figures of Miss Wilman's Class I and Burkitt's Series II. All the figures reproduced here are direct tracings from the originals.

Fig. 3 includes a beautifully engraved quagga from the farm Afvallingskop in the Jacobsdal district of the S.W. Free State, over 200 miles south of Gestoptefontein. This is the hill to which I took Burkitt in 1927, where we worked out the series quoted above—but we missed this engraving as

* *Cp.* Burkitt, Prehistory, pl. ix, D, p. 351.

† *Cp.* Peyrony, "La Station Préhistorique des Jean Blanc," Bull. Soc. Hist. et Arch. du Perigord, p. 12, fig. 5 (1934).

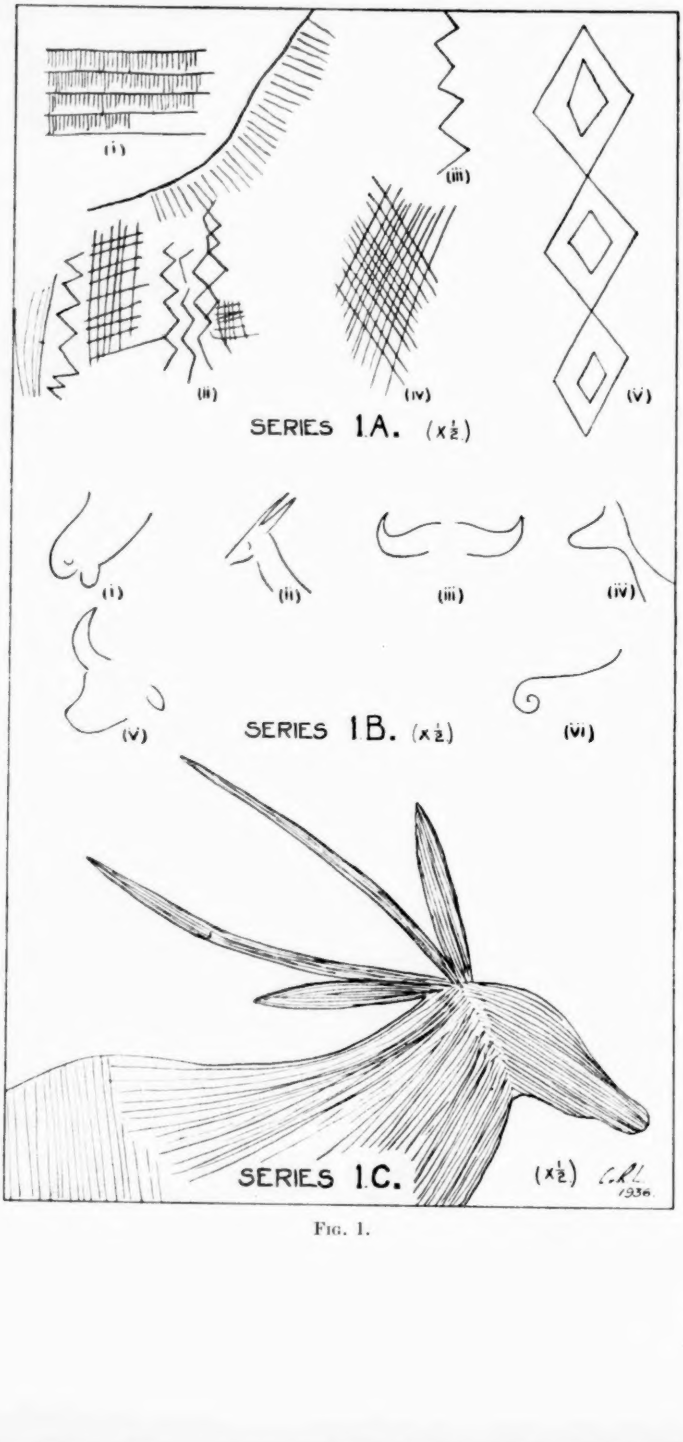
(i)
(ii)
(iii)
(iv)
(v)
SERIES 1.A. (x½)
(i)
(ii)
(iii)
(iv)
(v)
SERIES 1.B. (x½)
(vi)
SERIES 1.C.
(x½)
1936

Fig. 1.

we missed others. The lines are so fine and faint that one can only see them in certain lights. From a technical viewpoint this belongs to Burkitt's Series I, but like the geometrical figures it represents an earlier stage of the Series.

The bowman in fig. 3 is from the farm Doornhoek No. 24 in the Klerksdorp district of the S.W. Transvaal. The figure is pecked out in the style

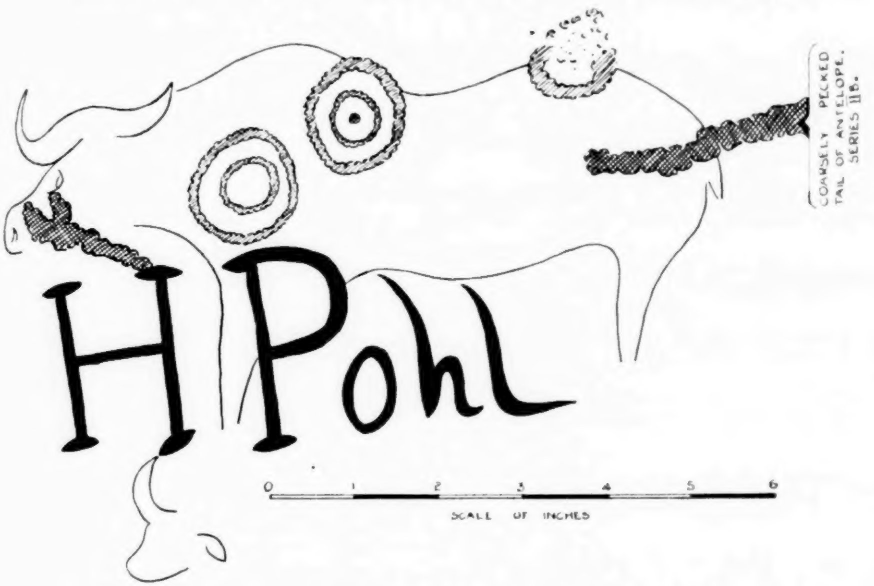

FIG. 2.—Finely engraved buffalo in Series I (B) under finely pecked concentric rings in Series II (A), and under coarsely pecked antelope (tail only shown) in Series II (B)—the whole mutilated in Series IV by H. Pohl on "Sept. 3, 1876."

of Series II, but the bow is finely engraved in the earliest Series I style. That the pecking and engraving techniques are contemporaneous here is proved by the fact that the engraved line passes *under* the pecking in one place and *over* it in another. It would seem that the bow was added last and the pecking then touched up, leaving the engraved line over in one place and under it in another. Of this there can be no doubt, for the incrustation or patination is consistent throughout. The faintness of the engraved line can be appreciated when it is stated that the owner of the farm (Dr. Orford) and his family have kept a careful eye on the engravings for many years. Miss Margaret Orford and others have photographed, copied and taken rubbings of most of the figures, but the engraved bow

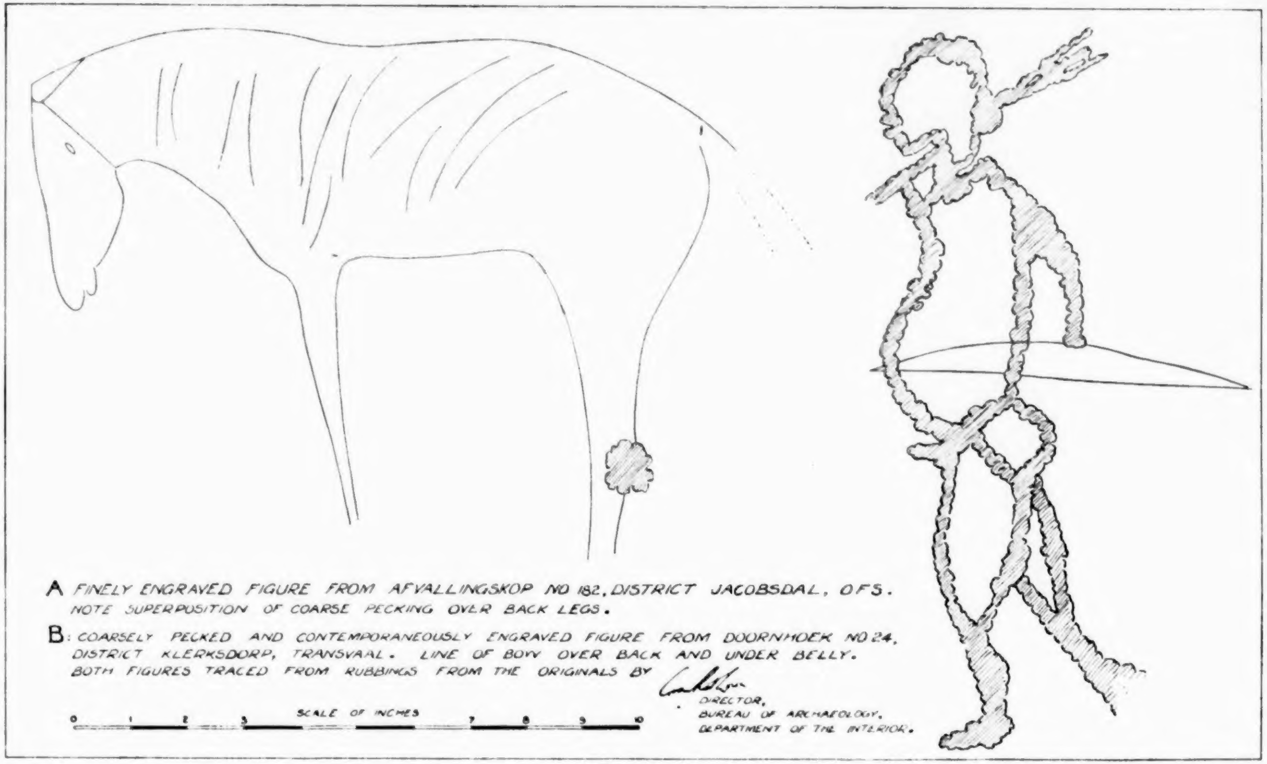
A FINELY ENGRAVED FIGURE FROM AFVALLINGSKOP NO 182, DISTRICT JACOBSDAL, O.F.S.
NOTE SUPERPOSITION OF COARSE PECKING OVER BACK LEGS.
B: COARSELY PECKED AND CONTEMPORANEOUSLY ENGRAVED FIGURE FROM DOORNHOEK NO 24, DISTRICT KLERKSDORP, TRANSVAAL. LINE OF BOW OVER BACK AND UNDER BELLY.
BOTH FIGURES TRACED FROM RUBBINGS FROM THE ORIGINALS BY
DIRECTOR,
BUREAU OF ARCHAEOLOGY,
DEPARTMENT OF THE INTERIOR.
0 1 2 3 SCALE OF INCHES 7 8 9 10

Fig. 3.

was not seen until quite by chance we examined the figure here reproduced in the light of a setting sun and saw the bow.

Excluding this bow, all the scores of figures at Doornhoek belong to Series II. Several are among the most beautiful I have seen, and Plate XI is specially reproduced to show a fine appreciation of composition. This is the only true composition I have seen. In front of the hunter is a natural saucer-like depression in the rock which holds water after rain, and perhaps even dew. The artist depicts a hunter approaching the water and a flight of wild-fowl leaving it. From left to right the length of the picture is about four feet.

As a result of these discoveries I suggest extending the divisions as follows:—

Series I. (A) Simple and finely *engraved* geometric figures.
(B) Finely *engraved* figures of animals in outline only.
(C) *Engraved* silhouettes, the silhouette being filled in with incised lines running more or less parallel to the nearest outer edge.

Series II. (A) Finely pecked figures (in profile and silhouette).
(B) Coarsely pecked figures (in profile and silhouette).

Series III. Finely pecked and rubbed figures.

Series IV. Modern. Metal graving tools, etc.

Series I (A), (B), and (C) may be contemporaneous. There is nothing to suggest a chronological sequence. Series II (A) and (B) have every indication of being contemporaneous, but figures in Series I only consistently underlie figures in Series II. The partially pecked and partially engraved figure at Doornhoek is the only exception known. For the rest, the four Series given are chronological.

From the simplest beginnings in Series I (A), where we seem to be in contact with an experimenting in the art of engraving, we see the development of the finest craftsmanship in Series I (B), with a slight carelessness in the filling-in that characterises Series I (C), the figures and finish of which are not nearly so good as the simply *engraved* outline work of Series I (B).

It is extremely unfortunate that so few of these engravings are known. The work is so fine and the rocks used as a background so weathered, that most have no doubt disappeared, but it is hoped that this note will inspire those who have opportunities for field-work to make a more exhaustive search for further examples.

The study is still in its infancy and several sites need to be exhaustively examined and described before we can proceed with any real certainty.

There can be no doubt that the technique underlying all the work in

Series I demands knowledge of a graving tool of sorts, and it is a strange fact that, with a single exception, no such tool has yet been found at or near any site. It must of course be remembered that all these sites are on the open veld and, with hardly an exception, remote from factory and home-sites. With the passage of time, the few tools that were dropped may have been washed away or buried; but it is remarkable that of the scores of sites on which artifacts have been collected, these artifacts have been predominantly Smithfield "A" and "B" in facies, and only one poor graver recovered—from the well-known site at Schoolplaats on the left bank of the Vaal immediately down-stream of the Vaal-Hartz Development Scheme Weir near Warrenton, where all the recognisable figures are in Series II.

The filled-in engraved figures of Series I (C) appear to mark the culminating phase of incised work, for there is a sudden break followed by the application of an entirely new technique with just a vestige of the old retained (Doornhoek). In Series II and III there is no engraving in the real sense of the word. The process can only be described as pecking and chipping—a variety of engraving no doubt, but a very distinct form. In Series III the art reaches its highest phase, for the finest and most "classic" pictures undoubtedly belong to this Series—and then once more there is a sudden cessation of the Art and an annihilation, as it were, of the artists.

Associated Implements.

Burkitt mentions the discovery of stone implements of Smithfield facies in the vicinity of certain sites, and I can only add that whenever artifacts have been found at or near these sites (and very many have been found) they are almost without exception of Smithfield A and B types—mainly A.

It is obviously impossible to prove contemporaneity of engravings and artifacts, but when dozens of widely separated sites consistently yield artifacts from a known lithicultural horizon, it is reasonable at least tentatively to assume that the engravings and pecked-out figures were made by the same folk who made the artifacts.

With the passage of time and as a result of much work at these sites, I have been driven to the conviction that, excluding Series IV, the vast majority of the engravings and peckings were done by folk who practised the "A" and "B" phases of the Smithfield Culture—particularly "A" folk (6).

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(2) Holub.—"Sieben Jahre in Sud Afrika" (1872–1879), Wein, 1880.

(3) Holub.—"Von den Capstadt ins Land der Maschukulumbe," Wein, 1890, vol. i, p. 141, and illustration on p. 105.

(4) Želizko.—"Felsgravierungen der Sudafrikanischen Buschmanner," Leipzig, 1925.

(5) Burkitt.—"South Africa's Past in Stone and Paint," Cambridge, 1927.

(6) van Riet Lowe.—"The Smithfield Industry in the Orange Free State," Ann. S.A. Mus., vol. xxvii, pp. 173 *et seq.*, 1929.

Neill & Co., Ltd.

C. van Riet Lowe.

HYDRODICTYON IN SOUTH AFRICA. WITH NOTES ON THE KNOWN SPECIES OF *HYDRODICTYON*.

By M. A. Pocock.

(With Plates XII and XIII and two Text-figures.)

(Read August 19, 1936.)

Introductory.

Hydrodictyon has now been known from South Africa for over twenty years; the scarcity of printed records makes exact reference difficult, but some form of *Hydrodictyon* had certainly been collected before 1912. In Marloth's Flora of South Africa (1913, vol. i, p. 10), W. T. Saxton mentions the occurrence of "*Hydrodictyon reticulatum*" on the Cape Flats, but the figure given (*loc. cit.*, pl. ii, fig. 1) is undoubtedly not that species but *H. africanum*, which was described and named by Yamanouchi (1913) from material obtained in Chicago from a culture of soil from the Cape Flats. He investigated the structure, cytology and to some extent the development, as seen in this cultured material. Further work on this species, also on material raised in culture, was done by Miss Wigglesworth (1925). Apart from these two papers, no account of *Hydrodictyon* in Africa has been written, and as yet there is no published record of any critical work carried out in Africa on these algae, either in their natural state or in culture on the spot. For some years past, however, a large number of field observations and records have been made by Miss E. L. Stephens and by the writer; in addition, during the last three or four years the latter has carried on a series of observations on the development and life-history of *Hydrodictyon* in South Africa. Of these the present paper is the outcome.

In certain of the temporary rainwater pools or vleis which form on the Cape Flats during the winter months two very different species of *Hydrodictyon* regularly occur. Of these, one, *H. africanum*, is sufficiently distinctive, but, so far as is at present known, is more localised and less certain in its occurrence than is the second species, which is widespread in South Africa. The latter has been variously identified, first as a large form of *H. reticulatum* (L.) Lag., and more recently as *H. indicum* Iyengar. A closer study of it, however, reveals very marked deviations from either of

these two species; it seems advisable therefore to place on record what has been learnt of its structure and development and to give it a name for future reference. Since the flat saucer-shaped form of the net, even when adult, seems to be the characteristic which most distinguishes it from *H. reticulatum*, it is proposed to name the new species *H. patenaeforme*.

Hydrodictyon patenaeforme, sp. nov.

H. rete patenaeformi, plerumque plus minus orbiculari, numquam saccato, e coenocytis circa 512–1024 (2^9–2^{10}) in strato unico rarius in parte centrali duplicato dispositis, coenocytis cylindricis, saepe maximis. Propagatio esexualis ignota; propagatio sexualis divisione repetita cytoplasmatis fit, gametis permultis minutissimis biciliatis, piriformibus, puncto rubro laterali, apice achromato, jam intra cellulam matricalem agitantibus, per rupturam plerumque lateralem membranae effugentibus denique natantibus tum inter se conjugantibus; zygotis quadriciliatis, mox in zygosporas minutas globuliformes perdurantes transientibus.

Net plate-shaped, usually more or less circular in outline, never saccate; composed of a single layer (rarely two-layered in the centre) of cylindrical coenocytes, about 512–1024 (2^9–2^{10}) in number, often very large. Asexual reproduction unknown; sexual reproduction by repeated division of the protoplast producing a very large number of minute biciliate gametes, pear-shaped with lateral red eyespot and colourless apex, which at first move within the mother cell, are liberated through the rupture (usually lateral) of the membrane, for a time swarm then conjugate in pairs to form quadriciliate zygotes, which after a short time are transformed into minute globular resting zygospores.

Size of net very variable in different localities, depending greatly on external conditions; often 14–20 cm. in diameter before gamete-formation begins.

Individual coenocytes may attain a very great size, up to 4 cm. or more long, often 1·5–2 mm. wide, by 2–3 cm. long.

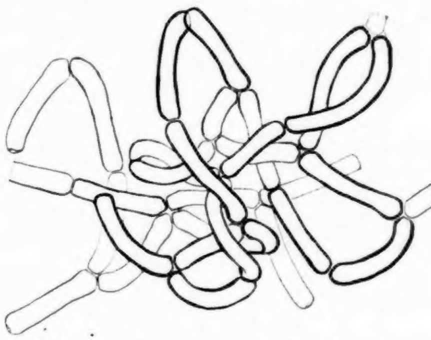
Gametangium crass. ·5–1·7 mm., long. 5–20 mm.
Gamete crass. 4–5 μ, long. 5–9 μ.
Zygote (motile) crass. 5–9 μ, long. 7–11 μ.
Zygospore diam. 6–8 μ.
Polyhedron (mature) cum. spin. diam. ad 80–89 μ.
Net, newly formed, diam. 119–195 μ.

Occurrence.

Widespread in South Africa, in seasonal pools and vleis. Collected from the Cape Flats from May to October (De Klip; Groen Vlei; Ottery Road, sandpits and ditch at roadside, etc.); roadside pool between Robertson and Ashton (April 1935); quarry pool, Butts Road, Kimberley (J. H. Power, November 1931; Pocock, January 1934); Grahamstown (L. Britten, 1931, January 1932); Winberg (M. Radloff); Rietfontein, near

Johannesburg (M. E. Blenkiron, March 1928); Umzimvubu River, near Port St. John (Blenkiron, January 1928).

As the coenocytes enlarge they tend to twist spirally about one another, contorting the net in a characteristic fashion so that it eventually forms a tangled mass, obscuring the essentially saucer- or plate-like structure (text-fig. 1). The hyaline wall, thin and smooth when young, often becomes much thickened in old coenocytes. The chloroplast is parietal, continuous when young but tending to become reticulate as development proceeds; embedded in it are numerous large, more or less rounded pyrenoids which appear a brighter green than the surrounding chloroplast. The zygotes formed as the result of fertilisation are motile for a time, then settle down



TEXT-FIG. 1.—*Hydrodictyon patenaeforme.* Fragment of an older net showing tangling caused by the spiral twisting of the developing coenocytes. × about 2.

in clumps and form minute thick-walled rounded orange-coloured resting spores.

While the records given above are by no means exhaustive, they serve to show how widespread this species is, in regions of both winter and summer rainfall. A further study of its distribution with observations of soil, pH concentration and mineral content of the water, temperature, etc., would probably yield very interesting results. A few observations made in connection with work on *Volvox* in 1931 (Pocock, 1933, p. 541) serve to indicate that whereas *Volvox* at the Cape is found in pools in which the normal pH concentration is neutral or slightly acid, *Hydrodictyon* thrives only in those vleis which, although neutral when first formed, soon become alkaline, the alkalinity increasing as the season advances. Further, from the few data at present available, it would appear that *H. africanum* flourishes in vleis with a higher degree of alkalinity than those in which *H. patenaeforme* occurs. Many more observations are, however, necessary to confirm these tentative generalisations. The two species occasionally

occur in the same vlei, but this is rare; only one locality is known to the writer where *Volvox* and both species of *Hydrodictyon* have all been found in one and the same piece of water, namely Groen Vlei * on the Lansdown Road, Cape Flats, and there they did not occur simultaneously.

In several vleis further out on the Flats, where there is a good deal of surface lime, the pH reaches a very high value as the season advances; here *H. africanum* occurs in abundance, but *H. patenaeforme* has not yet been recorded.

Life-history.

Young nets make their appearance within a few days of the formation of the pool. Cultures have been made by putting small quantities of vlei soil in glass vessels and then adding water; the cultures are then so placed that they can get the morning sun without becoming unduly heated. The following are records of two such cultures:—

Culture I.

Monday, 9th January 1933.—Rain water added to soil from Kimberley.

Wednesday, 11th January, 5 p.m.—Occasional polyhedra up to 40 μ diameter seen; during the evening others up to 80 μ were seen, by midnight division in numerous polyhedra was well advanced, and by 1.30 a.m. net formation was complete in many cases.

Culture II.

Saturday evening, 14th January 1933.—Water added to soil from De Klip, and small quantities of the soil surface examined daily.

Sunday.—Numerous resting cells—some golden, some green—seen; but it was not possible to say definitely which of these were *Hydrodictyon* zygospores.

Monday evening.—Numerous polyhedra, some small ($15 \times 18\ \mu$) with processes just forming, others larger ($26 \times 26\ \mu$) with typical spine-like processes at the angles.

Tuesday evening.—Many large polyhedra ($\rightarrow 58\ \mu$) and a few fully formed nets.

Thus in both these cultures net formation was completed, in some cases at least, in under three days from the time when water was added.

* This vlei is an extensive one much frequented by wading birds; in the dry season it serves as grazing ground for cattle; in winter, if there have been good rains, the whole field may be submerged, the resultant vlei being very rich in algal growths. *Volvox* has been recorded by Miss Stephens as occurring in the freshly formed vlei, although not in large quantities, but it is chiefly remarkable for the large quantities of *H. patenaeforme* it produces. Writing of this vlei on 5th December 1929 the writer records of the latter species: "A month or so ago there was an acre of it or more, 1–2 feet thick, glorious stuff, in the left-hand side German Church vlei (= Groen Vlei). Now there is not a sign of it, but, to my surprise, a certain amount of *H. africanum*."

At De Klip, of the half-dozen pools which annually form in and round the granite outcrop (*cf.* Pocock, 1933, p. 542), two only have yielded *Hydrodictyon patenaeforme*, and of these in the last three or four years only one has produced it in any quantity, although only a few yards separate the two pools. If, a few days after rain has first filled this pool, the bottom is gently disturbed and the resulting suspension collected, many thousands of polyhedra and microscopic nets, just visible to the naked eye, may be obtained.

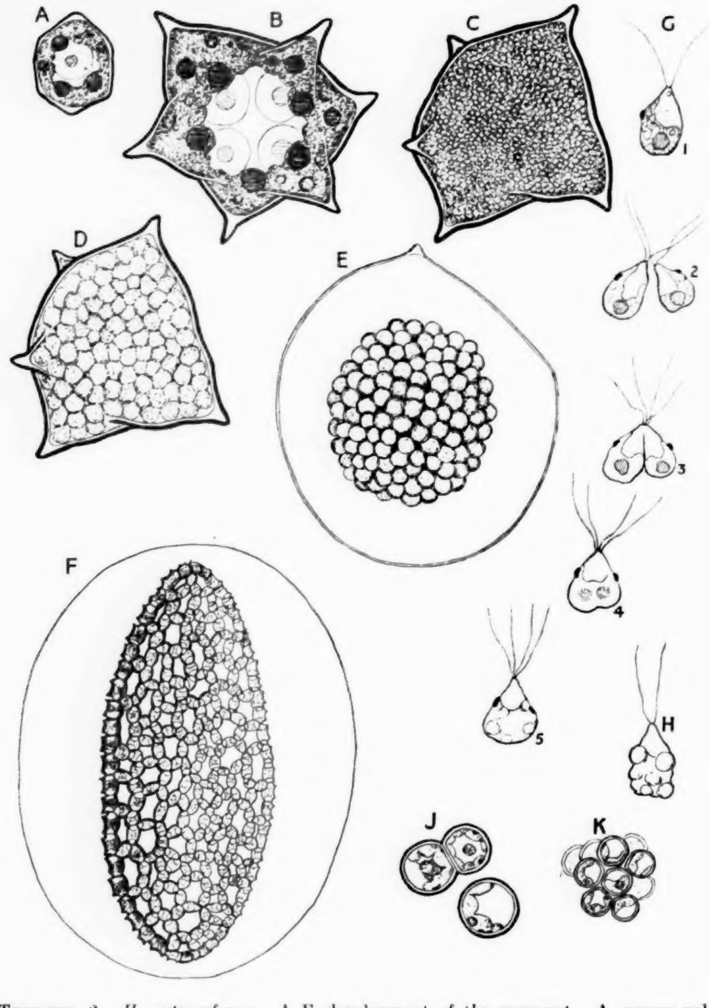
Development of the Polyhedron.—The mature polyhedron (Pl. XII, figs. A, B) is essentially similar to that described and figured for *H. reticulatum*, *i.e.* a many-angled body with the angles drawn out into more or less conical points, but it tends to be more regular in shape than in that species. Very often there are six such processes more or less equally developed, so that the polyhedron has a tendency towards an octahedral form, the sides being more or less equilaterally triangular with curved surfaces.

There is, however, considerable divergence from this form, the number of angular processes varying greatly—polyhedra with 5, 7, 8, and even 9 angles having been observed. On the whole, the polyhedra in the Kimberley material tended to greater regularity than did those from De Klip.

The youngest polyhedra seen ($15 \times 18\,\mu$) were small, with the angular thickenings only just beginning to appear (text-fig. 2, A). The size increases rapidly, and a central colourless zone in which the nucleus is situated is soon differentiated. In the living polyhedron the nucleus is difficult to distinguish—in one large one, where division was just beginning, four large nuclei were distinguishable (fig. 2, B). In the adult polyhedron the massive, intensely vivid green chloroplast lines the entire wall, extending into the bases of the angular processes and enclosing the large central colourless region, into which the numerous pyrenoids project. In addition, it includes various smaller granules and globules, but the structure of the chloroplast itself is homogeneous, without any sign of reticulation.

Formation of the Young Net.—The appearance of the polyhedron begins to change; first the central clear zone and the large pyrenoids are no longer distinguishable, the colour appearing evenly distributed throughout the protoplast, which now appears coarsely granular (fig. 2, C). In the course of an hour or two the granular appearance gradually changes and the contents are seen to be divided into a number of small polygonal masses (fig. 2, D), the "paved" appearance noted by Pringsheim (1860, p. 9). In this state the polyhedron remains for some time, possibly another hour or so, apparently quiescent, except that the polygonal masses become rather more clearly defined.

Then a slight quivering begins among the polygonal bodies, now somewhat rounded, quickly changing to an active vibratory movement.



TEXT-FIG. 2.—*H. patenaeforme.* A–F, development of the germ-net. A, young polyhedron; B, older polyhedron with four nuclei; C, developing polyhedron, contents granular in preparation for zoospore formation; D, contents divided, "pavement" stage; E, zoospores rounding off, wall expanding to form the vesicle, remains of one spine-like process still visible; F, fully formed net seen obliquely, still enclosed in the large vesicle somewhat diagrammatic. G–K, Sexual reproduction: G, gametes —1, normal gamete; 2–4, conjugation; 5, motile zygote. H, gamete from a net which had changed colour prior to gametogenesis. J, recently formed zygospores; one with two eyespots still visible. K, clump of zygospores.

A–E, K, × 500; F, × about 350; G–J, × 1000.

Coincident with the start of this movement, the wall of the polyhedron begins to expand, at first slowly, then with considerable rapidity (fig. 2, E, F). The wall is a single homogeneous layer of a clear hyaline substance, and there is no distinction into an inner and outer layer, nor is there any throwing off of a process-bearing outer coat as described and figured by Pringsheim in *H. reticulatum* (*loc. cit.*, p. 9, and figs. 19, 20). The angular thickenings here are evidently merely reserve wall material in no wise differing from the rest of the wall, serving for protection against attack by small animals, and ultimately used up in the formation of the delicate wall surrounding the large vesicle in which net formation is proceeding. In *H. patenaeforme*, therefore, the "spines" of the polyhedron, though similar in appearance to the processes so characteristic of *Pediastrum*, are of a somewhat different nature. If the expansion of the wall is watched carefully, the gradual using up of the material stored in the angular thickenings can be clearly traced, until they finally disappear; in a few cases only could remains of the spines be seen here and there as slight thickenings of the delicate vesicle wall. Usually the latter is a delicate membrane of the same thickness throughout, ellipsoid or nearly spherical in shape, allowing ample room for the developing net; it continues to enlarge slowly with the growing net, but ultimately gelatinises completely and disappears.

Meanwhile, movement in the green mass has continued to increase in activity, apparently at first serving merely to separate the component parts, which may for convenience be called zoospores. Soon, however, it can be seen that the mass is increasing in one dimension, decreasing in others, *i.e.* the zoospores are gradually rearranging themselves in a single layer, more or less in one plane (fig. 2, F). The movement is never a free one, but always vibratory, a kind of mutual jostling until the required position is attained, suggesting that some form of connection, whether actual protoplasmic connections or not, does exist between the individual zoospores (*cf.* Klebs, 1896, p. 135). This could not, however, be proved, but, on the other hand, neither could the presence of cilia be detected. It seems probable, however, that cilia are produced—possibly only in a rudimentary form, but sufficient to impart the characteristic vibratory movement to the zoospores without giving rise to locomotion. This movement is strongly reminiscent of the vibrations of the developing cilia in an inverting *Volvox* colony or spermatozoid bundle. Whatever the underlying cause, the result is always, in normal development, the same—*i.e.* the formation of a more or less flattened net, usually turning up slightly at the edges and therefore saucer-shaped, more or less rounded or broadly elliptical in surface. It is typically one-layered, but occasionally a net is seen with a few meshes in the centre showing two layers (Pl. XII, fig. E).

Movement was never long continued; cessation of movement usually

starts at the outside and progresses rapidly inwards, so that the edge of the net is the first part to become fixed in its permanent form. Normally before this occurs, the zoospores have already arranged themselves in a single layer, but occasionally the flattening out has not been complete, hence the occurrence of nets with double or even treble-layered portions. Sometimes, too, single zoospores lag behind the majority, but the lagging is seldom considerable, and in normally developing nets the component zoospores show marked unanimity, all tending to cease movement simultaneously, once quiescence has started.

A single example may be described as typical and serving to give some idea as to the dimensions and times involved. The material under observation was a Kimberley soil culture, and a slide with a number of polyhedra was being watched through the night. The individual in question was first observed at 12.10 a.m., when its contents were already granular in appearance, indicating the beginnings of division. Its smallest diameter was 49 μ, its largest (including spines) 71 μ (fig. 2, C).

1.5	a.m.	Differentiation into zoospores apparent ("pavement" stage). Fig. 2, D.
4.59	,,	First sign of movement seen; wall beginning to expand, 84×97 μ traces of one angular thickening still present. Fig. 2, E.
5.3	,,	Vesicle 88×102 μ, wall equally thin throughout, movement very active.
5.6	,,	Vesicle 102×130 μ, net 119 μ, zoospores in one plane, edge of net nearly in place.
5.12	,,	Vesicle 141×155 μ, net 141 μ, movement slowing.
5.17	,,	Vesicle 155×203 μ, net 155 μ, movement finished. Fig. 2, F.
9.20	,,	Vesicle disappeared, net 208 μ.

The vesicle continued to expand slowly, the wall becoming more and more tenuous until it ultimately disappeared. The result was a very beautiful perfect net (shown edge-on in the figure), somewhat oval in shape, with the edges turned up slightly.

Here, as is always the case, the cells forming the edge of the net showed characteristic processes where they had not made contact with one another as they would normally have done in any other position in the net (Pl. XIII, fig. B). These processes were noticed and described by Pringsheim (*loc. cit.*, p. 12), and show well in the photograph of a young net figured by Mainx (1931, pl. xx, fig. 17). The former compares them with the processes round the edge of a *Pediastrum*, which undoubtedly originate in the same way, although their ultimate fate may differ. In *Hydrodictyon* these processes are still traceable in fairly well-grown nets.

The number of zoospores formed in each polyhedron is large, several hundred at least, considerably more than in *H. reticulatum* germ-nets.

Pringsheim (*loc. cit.*, p. 10) gives the number there as "at most two to three hundred," sometimes considerably fewer; Mainx does not mention the number of zoospores, but in the photograph of the young net which he figures there are 128 (*i.e.* 2^7) coenocytes. In the Kimberley cultures counts of coenocytes in more or less complete young nets were as follows: 462, 489 (both a good deal torn), 503, 508, 511, all approximating to 2^9, *i.e.* 512; a larger net in which a count was made was torn in several places and therefore incomplete: it contained 945 coenocytes, and therefore probably resulted from 10 successive simultaneous divisions of the polyhedron nucleus. The larger number of zoospores is probably correlated with greater size of the mature polyhedron. As compared with the usual cylindrical asexually formed net of *H. reticulatum*, on the other hand, composed of many thousands (some thirty thousand is the number usually given; Al. Braun, 1851, p. 147, says from 7000–20,000) of coenocytes, the number in a normal net of *H. patenaeforme* is exceedingly small, since the germ-net persists, reaching a large size.

As regards the form of the germ-net in *H. reticulatum* there is some divergence of opinion. Pringsheim (*loc. cit.*, p. 10) states that, after the division of the "polyeder," "the resulting swarm spores . . . group themselves into a small net which often consists of only a few cells forming a single- or almost single-layered structure, but which usually, as in the larger polyeders richer in contents from which a larger number of swarm spores arises, forms, AS IN THE WELL-KNOWN NETS OF *Hydrodictyon*, A PERFECT HOLLOW SACK," and later (p. 12) he refers again to the hollow sac-like form which may occur in the first young net. Mainx (*loc. cit.*, p. 513), on the other hand, states that the primary net formed from the polyeder "is, in contrast with the sac-shaped nets formed by zoospore formation, always formed in one plane (Taf. XX, fig. 17). It grows, increasing rapidly in size, and soon begins to reproduce by means of zoospore formation."

From the latter account it would appear that while the primary nets are similar in form to those of *H. patenaeforme* they are soon replaced by asexually formed cylindrical nets. Obviously it is much to be desired that further observations of polyeder development in *H. reticulatum* should be made in order to clear up this point. It is possible, of course, that there was some error of observation on the part of the older investigator and that he was misled by the form of early developing asexual nets in his material, but his figures and description do not suggest this. Unfortunately, the figure of germ-net formation (*loc. cit.*, fig. 20) which is reproduced in all accounts of the alga is the one showing what Pringsheim himself states is the less usual condition, while the other (fig. 19), showing the usual state of affairs, has very seldom been reproduced. The possibility of the existence in

Europe of more than one form of *Hydrodictyon* must also be taken into consideration.

Subsequent Development of the Net.—When first formed, the net consists of small, uninucleate, barrel-shaped units, each with a band-shaped parietal chloroplast more or less completely encircling the centre of the cell and containing a single pyrenoid; both ends of the cell are colourless (Pl. XII, C, D). As development proceeds, the shape of the cells alters, becoming cylindrical (Pl. XIII, A), the chloroplast becomes more extensive, there are at first two pyrenoids and two nuclei (Pl. XIII, C) then many, while the chloroplast develops still further, completely lining the cell-wall, in which condition it usually remains until a later stage in development, provided external conditions are favourable.

The nets may eventually reach a very large size, fundamentally, however, always retaining the structure of a single-layered, saucer- or plate-shaped net, although this is largely obscured by the tendency of the extremely turgid coenocytes to twist spirally round one another, thus causing the whole net to twist so that it finally forms a tangled mass (text-fig. 1). Individual coenocytes may reach as much as 4 cm. or more in length by about 2 mm. in diameter. They are in a very high state of turgidity, but the cell-wall normally remains comparatively thin; ultimately, however, if gamete formation does not previously supervene, it may become more or less thickened, as is also the case in *H. reticulatum* (*cf.* Braun, 1851, p. 204). In such old coenocytes occasional peg-like ingrowths, similar to those described by Iyengar in *H. indicum* and also frequently found in old coenocytes of *H. reticulatum*, may occur, but they are by no means common nor are they characteristic of any but old nets. Nets may often be found in which uneven development has taken place, the coenocytes on one side being still small and green, while in other parts of the net they may be more than double the size; in such cases it is often found that the less developed side has been pinned down by a twig or some other obstruction.

The colour of the net is at first a deep vivid green, but later may change to a golden or orange-yellow colour, which in mass forms a very striking feature of the landscape. That this is mainly a result of insolation is shown by the fact that in deeper pools, such as Groen Vlei, where there is annually a very rich growth, the nets on the surface become brilliant orange-yellow, while those deeper down, protected by the thick surface growth, are still bright green. In many cases the chloroplast, which in developing nets is evenly dispersed over the whole inner surface of the wall, tends to become markedly reticulate; in other words, the increase in the surface area of the chloroplast does not keep pace with the increase in the area of the wall. This reticulation may appear in comparatively young nets if overcrowded or in otherwise unfavourable conditions, and appears to be a purely physio-

logical condition quite unconnected with reproduction and very different both in appearance and nature from the reticulate condition which precedes reproduction in *H. reticulatum.*

Breaking up of nets caused by the separation of the individual coenocytes is also sometimes seen in old material in certain conditions, but this is by no means of general occurrence even in old nets. Where it does occur it is associated with much-thickened walls and abnormally high turgidity.

Reproduction.—1. *Asexual.*—So far no asexual reproduction has ever been observed—daughter nets are apparently never formed within the coenocytes, hence the absence of the cylindrical nets so characteristic of *H. reticulatum.*

2. *Sexual.*—On the other hand, sexual reproduction must be of regular occurrence, although the number of records of the actual observance of gamete formation are comparatively few. It has, however, been observed on several occasions both in culture and in material brought in from the field. Coenocytes may function as gametangia while still quite small (·5 mm. wide by 5 mm. long) or after reaching a considerable size (largest seen 1·7 mm. wide by over 2 cm. long). The contents of the coenocyte break up into an enormous number of minute biciliate swarmers; as movement begins the protoplast tends to shrink and the moving mass of swarmers collects in the centre of the cell. Movement is at first of the vibratory type seen in the formation of the zoospores in the polyhedron, but the gametes soon become free from one another, the cilia are fully developed, rather longer than the body of the gamete, and the gametes begin to move about inside the cell at a great rate. The actual method of escape could not be determined; there did not appear to be any definite pore of escape, and there was no sign of the protrusion of an inner vesicle, as described and figured by Cohn in *H. reticulatum* (1853, p. 122, Tab. 19, figs. 11, 12). Apparently the pressure of the swarming gametes ultimately tears the weakened wall, allowing of their escape. Bearing in mind the very small size of the gametes (from about $4 \times 5\ \mu$ to $5 \times 9\ \mu$) and the comparatively enormous size of the gametangia, the number of gametes formed in a single coenocyte must be immense, hundreds of thousands rather than the forty thousand usually estimated for *H. reticulatum.** Further, since all the coenocytes of a net may function simultaneously as gametangia, and since a net may consist of over a thousand of these, it follows that a single net may produce not thousands but millions of gametes. It does not, however, necessarily happen that all the cells of a net simultaneously form gametes; on the contrary, it is apparently common for some coenocytes to function as gametangia while others continue to enlarge and either become

* But Braun (Verjungung, p. 21) gives from thirty to one hundred thousand; see Cohn, *loc. cit.*, p. 120.

gametangia at a later stage or not at all, in which case they play no part in reproduction. It seems probable that this sporadic formation of gametangia in a net is in part at least responsible for the occurrence of dissociated coenocytes in old growths of the alga. Coenocytes functioning as gametangia are most often green, but gametes may also be formed in coenocytes which have changed colour from green to orange, in which case the gametes are themselves orange in colour and no further colour change takes place in the zygospore.

The gamete (fig. 2, G, 1) is a very small, rather irregular, more or less pear-shaped body, the anterior end slightly beaked with two fairly long cilia (about half as long again as the body length). There is a somewhat indefinite lobed chloroplast, which often contains several large globules apparently fatty in nature, particularly where the colour change from green to orange has already taken place. In the latter case, too, the irregularity of the shape is usually more marked (fig. 2, H). There is a small red eyespot slightly above the middle and the newly formed gametes are positively phototactic; at the apex can sometimes be seen one small contractile vacuole, but probably two are actually present. There is some variation in size—sometimes there are distinctly two sizes; otherwise the gametes are completely isogamous, both sizes being equally active, and, while conjugation between larger and smaller was seen, the smaller gametes also conjugated freely with one another.

Conjugation may begin directly on escape, or may be delayed, the gametes continuing actively motile for some hours. In some cases gametes from the same coenocyte were seen to conjugate readily with one another; *i.e.* like *H. reticulatum*, this species is, or may be, monoecious; but, since many nets may be discharging gametes simultaneously, the chances are that cross conjugation is of common occurrence. On one occasion a large *Hydrodictyon* culture from Kimberley soil was found to be in a state of active reproduction, whole nets or portions of nets forming gametes which were being liberated in countless thousands, so that the water of the tank was green with swarming gametes, many of them conjugating.

Conjugating gametes place themselves side by side, with their beaks touching, or at any rate inclined to, one another; in this position they rotate together, while at the same time darting about from place to place with great rapidity, the resultant rather spasmodic movement being highly characteristic. Actual fusion begins at the anterior end, and, once begun, proceeds rapidly to completion without any apparent slowing of the movement (fig. 2, G, 2–5). The resultant zygote (fig. 2, G, 5) is quadriciliate, with two eyespots, and remains actively motile for a time.

Critical observations of the behaviour of gametes and zygotes such as those described by Mainx (*loc. cit.*, p. 505) were not carried out, but no sign

of quiescence on the part of either gamete could be seen. One case of triple fusion was observed, the resultant zygote having six cilia. The ultimate fate of such zygotes, if they survive, would be exceedingly interesting to trace.

After a period of activity the zygotes settle down in clumps (fig. 2, K), round off, and clothe themselves with a comparatively thick hyaline wall; the chloroplast does not entirely fill the protoplast, and sometimes two eyespots were still discernible (fig. 2, J). If the colour has not already changed to orange, the change now begins, the green colour being entirely replaced by orange. So far as could be ascertained, the wall remains smooth, but unfortunately as yet the further changes in the zygote prior to the formation of the polyhedra have not been followed. Apparently, however, the zygospores, which form the resting spores during the time of desiccation, remain minute rounded bodies hidden in the soil. It seems probable that their development is as described by Mainx (*loc. cit.*, p. 512) for *H. reticulatum*, allowing for the differences in environment. Motile cells similar to those described by Mainx as formed on germination of the zygote were usually present with the polyhedra, but as the cultures were not pure and contained other unicellular forms it has not yet been possible to confirm their connection with *Hydrodictyon*.

Hydrodictyon africanum.

The life-history of this alga was not fully studied, but various points in its development were noted for comparison with *H. patenaeforme*. As in that species, polyhedra result from the germination of the zygospores and new nets are formed in the same way. Miss Wigglesworth (1928, p. 167) was unable to find this stage in her cultures, but in Nature it occurs normally. When first formed, the young nets are indistinguishable from those of *H. patenaeforme*; but, whereas in the latter species the barrel-shaped component cells of the newly formed net soon become cylindrical, in *H. africanum* the barrel shape not only persists but becomes progressively more marked (*cf.* Fritsch, 1935, p. 170, fig. 49, G) until finally a spheroidal form is attained, and when the coenocytes eventually separate they become perfectly spherical.

In this species, too, the formation of daughter nets is as yet unknown, the only form of reproduction so far observed being by means of gametes similar to those described above. Gamete formation has been observed even more rarely in this species, but there can be no doubt that it occurs on a large scale in Nature. Where it was observed, the gametangia were comparatively small (2–3 mm. in diameter). Apparently the large, separate, marble-like coenocytes so characteristic of the later stages of this alga,

and described by the country people who have noticed them as "green frog-spawn," are not concerned in reproduction. If kept in a cool shaded spot in plenty of water they may continue for months apparently unchanged, and bright green in colour. They ultimately disintegrate, but so far no trace of gamete formation has been observable in connection with this disintegration. In the field a period is put to their existence by the drying up of the vleis.

Discussion of the Relationship between the Various Species.

Hydrodictyon reticulatum (L.) Lag. is always described as a "sac-like net" (*e.g.* Rabenhorst, 1868, p. 65) or a "closed cylindrical net" (*e.g.* Brunnthaler, 1915, p. 105); and although Pringsheim (*loc. cit.*, p. 10) and Mainx (*loc. cit.*, p. 514) have shown that, sometimes at any rate, the primary net formed from the polyhedron is a flattened saucer-shaped structure, it seems obvious that this is but a transitory phase in the life-history of this species, the germ-net beginning at a very early stage to reproduce asexually by the formation of daughter nets. These daughter nets are composed of many thousands of cells and are of the well-known cylindrical, sac-like form in which *Hydrodictyon* occurs in Europe, North America (*cf.* Smith, 1933, p. 487), and probably North Africa—Egypt (Nayal, 1935, p. 20) and Algeria (Gauthier-Lièvre, 1931, pp. 23, 244). Pringsheim (*loc. cit.*, pp. 10 and 12), indeed, states that even the primary net is more often of the typical sac-like form.

In both the South African species, on the other hand, the primary net is always, with very rare exceptions,* flat and plate-shaped; and since here the primary net is not a passing phase but persists, and further, since daughter nets are not formed, the nets in any growth of *Hydrodictyon* are typically plate-shaped.

In *H. africanum* the ultimately spheroidal coenocytes, and their final regular disjunction into separate green spheres, are very distinctive, and the specific rank of this alga would appear to be beyond question.

As regards *H. patenaeforme*, however, the position is not so clear. The very different forms of the adult net in this species and in *H. reticulatum* would appear at first sight to afford sufficient specific distinction, but, on closer investigation, this question of net-form is found to be a secondary character dependent on the type of reproduction which dominates the life-

* As mentioned above, nets slightly two layered in the centre were occasionally seen; apart from these only two deviations from the typically saucer-shaped form were observed, one a somewhat funnel-shaped net (Pl. XIII, fig. D), and the other an irregular elongated cylinder. Both had been formed in material taken from culture and kept for some time on a slide under the microscope and may therefore have been due to abnormal development.

history of the species in question, and this in its turn is possibly ultimately determined by environmental conditions. It is thus possible that prolonged cultural experiments may show *H. patenaeforme* to be merely a local variety of *H. reticulatum*. On the other hand, they may establish its specific rank. Until this problem be solved, it is convenient to accept its very characteristic features at their face value and describe it as distinct. The number of coenocytes composing the net, while very much larger than in the primary nets of *H. reticulatum*, is of course small as compared with that of the component coenocytes of the ordinary asexually formed cylindrical net of that species.

In the species *Hydrodictyon indicum* Iyengar (1925, p. 315) it is not known what form the net assumes; Iyengar describes the nets as "resembling those of *H. reticulatum*" except in certain minor details, but no complete nets were seen. The specific differences on which Iyengar bases his description are (1) size, (2) the breaking up of the net by the separation of the coenocytes, and (3) the thick wall with numerous peg-like ingrowths. When these features are examined critically, their diagnostic value is found to be small. As regards size, the extreme recorded for individual coenocytes of *H. reticulatum* is 1·5 cm. (Smith, *loc. cit.*, p. 487), in *H. indicum* Iyengar records "coenocytes 10–16 mm. long by 1 mm. thick." *H. reticulatum* is notoriously variable both in size and appearance of individual coenocytes and of the entire net; *cf.* Rabenhorst (*loc. cit.*, p. 66), "Magnitudo aut retium aut gonidiorum maxime variat, pendet a conditione loci natalis." How dependent it is on external conditions is well illustrated by material in the writer's possession. Two young daughter nets about 2 cm. in length were isolated, one placed in a tumbler of tap water (Chelsea water), the other in a similar tumbler also containing tap water but in addition a layer of sterilised loam a centimetre thick. Otherwise both nets were in exactly similar conditions of light, temperature, etc. After five weeks' growth (25th February–31st March) the former measured nearly 7 cm. in length by ·35 cm. wide, while the latter in the soil culture measured 114 cm. in length by some 4–6 cm. in breadth (this being difficult to determine exactly); the coenocytes of the former were still minute though perfectly healthy and bright green, while those of the latter varied from 64 μ wide by 1257 μ long, to over 7 mm. in length; further, the latter had obviously not yet reached the limit of growth and showed no sign of daughter net formation.*

The breaking up of nets through dissociation of the component coenocytes, as mentioned above, appears also to depend to some extent

* Smith (*loc. cit.*, p. 487) states that in America perfect nets over 15 cm. long are rare, but that it is possible to find nets as much as 30 cm. in length. Prof. Fritsch has in his possession perfect nets of even greater size collected by Prof. Oliver "in paddy fields" in Egypt.

on external conditions and possibly also on reproduction where some only of the coenocytes have functioned as gametangia.

Finally, the thickening of the walls and the formation of peg-like ingrowths on the inner side are of common occurrence in old coenocytes of *H. reticulatum* and have also been observed in the two African species, though "pegs" are rare in *H. patenaeforme.*

It seems therefore probable that the material with which Iyengar worked was an old growth nearly at the end of its life, and only further investigation can show whether it is indeed a distinct species or only a large, but by no means excessively so, form of *H. reticulatum.** Fuller investigation may show that it and the African *Hydrodictyon* are indeed identical, but, until more is known of it, it seems better to regard the latter as a distinct species, *H. patenaeforme.*

If the form of the typical adult coenocyte be accepted as a basis for classification and the description of *H. indicum* be taken as it stands, assuming the net to be of the same form as in *H. reticulatum*, the following table would serve to summarise the distinctive features of the four species described:—

I. Net typically a closed, cylindrical sac of many thousands of cells.
    A. Net very variable in size; coenocytes cylindrical, in general not separating at maturity.
        1. *Hydrodictyon reticulatum.*
    B. Coenocytes cylindrical, large, separating at maturity.
        ?2. *Hydrodictyon indicum.*

II. Net flattened, single layered, of several hundred cells.
    A. Nets of several hundred cells; coenocytes cylindrical.
        3. *Hydrodictyon patenaeforme.*
    B. Nets of fewer (?) cells; coenocytes spheroidal, ultimately separating and becoming spherical.
        4. *Hydrodictyon africanum.*

Summary.

1. Two species of *Hydrodictyon* are known from South Africa—*H. africanum* Yaman., somewhat restricted in occurrence, the other wide-spread.

2. The second species is diagnosed as new and named *H. patenaeforme.*

3. Records from various parts of the country are noted, the habitat being always temporary pools which tend to alkalinity, thus contrasting with the normal habitat of *Volvox.*

4. *H. africanum* occurs in vleis of higher alkalinity than does *H. patenaeforme.*

* In spite of repeated search, Professor Iyengar has not been successful in finding *H. indicum* again; on the other hand, he has several records of typical *H. reticulatum* from various parts of India, while Mr. G. O. Allen also records it from North India.

5. Soil cultures were used for studying the life-history of *H. patenaeforme* as well as freshly collected vlei-material in varying stages of development.

6. Nets may develop from resting spores three days after the pool has newly formed. Polyhedra tend to be six angled, but may have from five to nine angular processes.

7. The formation of the primary or germ-net from the polyhedron was watched; in shape it is flattened or saucer-shaped, and the number of component cells may approximate to 2^9 (512) or 2^{10} (1024).

8. Asexual reproduction has as yet never been recorded.

9. Reproduction, so far as is known, is entirely sexual by means of isogamous biciliate gametes. The cells may be monoecious, but cross-conjugation is probably of common occurrence.

10. The quadriciliate zygote is active for a time, then settles down to form a very small rounded comparatively thick-walled resting spore, the subsequent fate of which has as yet not been followed prior to the formation of polyhedra.

11. The formation of polyhedra in *H. africanum* is noted; the germ-net is at first indistinguishable from that of *H. patenaeforme* but differs in development, the coenocytes becoming spheroidal.

12. The relation between the four species of *Hydrodictyon* is discussed and their distinguishing features summarised.

My thanks are due to Miss E. L. Stephens for the use of her records, to Professor Iyengar and Mr. G. O. Allen for information as regards the occurrence of *Hydrodictyon* in India, and to Professor Fritsch for much helpful criticism and advice.

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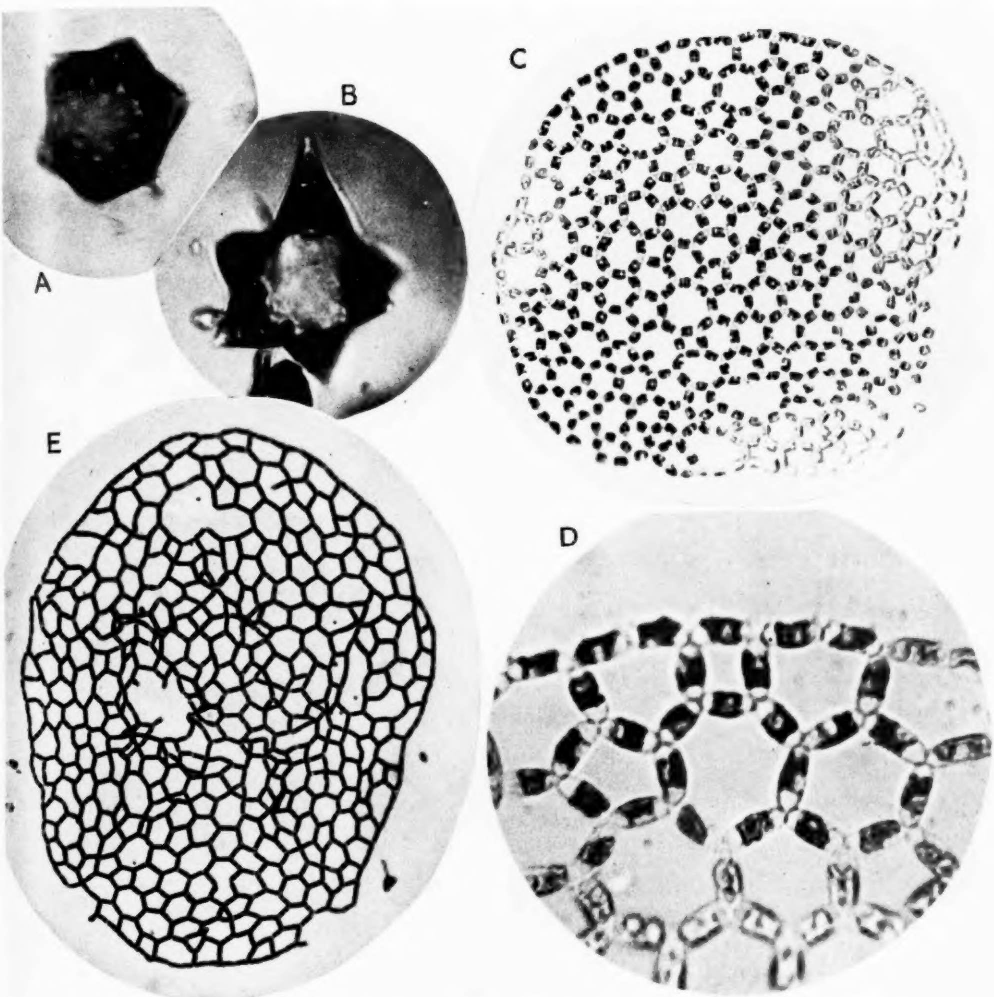
EXPLANATION OF PLATES.

PLATE XII.—*Hydrodictyon patenaeforme.*

A, B, Polyhedra. × 540. C, Young net, recently formed, showing barrel-shaped, uninucleate cells (489). × 285. D, Small portion of edge of C (top left) enlarged to show cell detail. × 1000. E, Older net showing parts of the centre two-layered. × 80.

PLATE XIII.—*Hydrodictyon patenaeforme.*

A, nearly complete older net (511 coenocytes), coenocytes now cylindrical. × 128. B, Small portion of A (top, right), stained with iodine, showing marginal processes, and chloroplast not yet continuous into ends of the coenocytes. × 730. C, Coenocytes from centre of an older net, binucleate and with two pyrenoids; chloroplast beginning to extend into the ends. × 730. D, Abnormal, somewhat funnel-shaped net. × 370.



Hydrodictyon patenaeforme.

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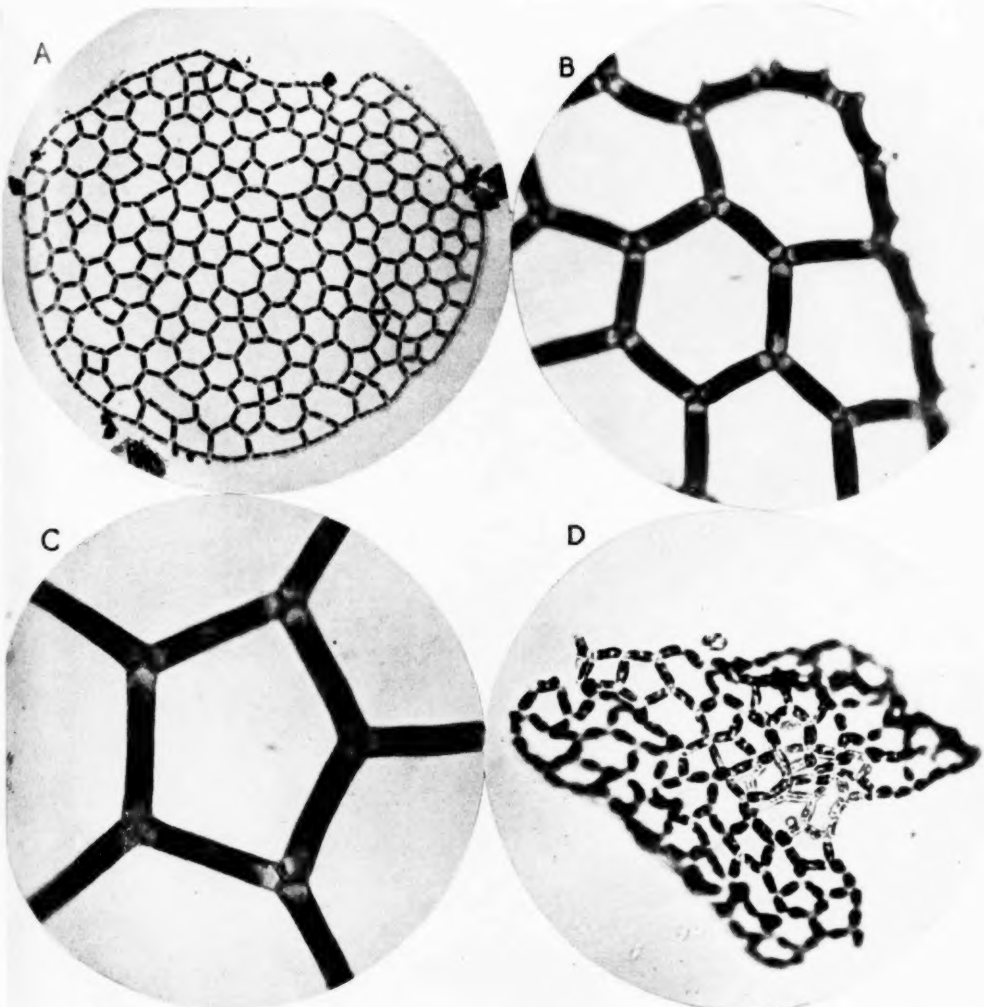

Hydrodictyon patenaeforme.

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SOME NOTES ON THE POLITICAL ORGANISATION OF CERTAIN XHOSA-SPEAKING TRIBES IN THE TRANSKEIAN TERRITORIES.

By G. P. Lestrade.

(Read September 16, 1936.)

The following notes are based upon information collected in 1929 on various occasions during a month's field-work in the Transkeian districts of Willowvale, Idutywa and Engcobo, from informants belonging to the Gcaleka, Mfengu and Thembu tribes respectively. In its main features, however, if not in all its details, the system here described is believed to obtain among all the Xhosa-speaking tribes in the Trans- and Ciskei, even among such tribes as were not originally part of the Xhosa-speaking group, but who, through long contact with this group, have become assimilated to it. The object of this paper is to describe the political organisation merely, and the social organisation will be touched upon only in so far as the purely political organisation is affected by it. It will be obvious, however, that it is seldom possible to separate the purely political system from the general social system of which it forms a part.*

Before considering in some detail the political organisation of these tribes, it will be advisable to cast a rapid glance at their territorial distribution. The Xhosa-speaking people live in what are called in South Africa *kraals*, *i.e.* small clusters of huts with their appendages in the way of places for cooking and storage, of pens for cattle, sheep and goats, and of some more or less central open space round which the huts, etc. are placed. Kraals are dotted all over the country at irregular intervals, the distance between one kraal and the next varying from about a hundred yards or less to several miles or more. But they are not dotted continuously: a number of kraals will be found relatively closely concentrated,

* No attempt is made to describe the changes which the system has undergone as a result of contact with Western Civilisation. On the whole it may be said that the results of such contact upon the political organisation dealt with gave one the impression of being relatively slight in the tribal area investigated, except in one or two respects to which reference will be made in their proper place. For general discussions of such effects in other tribal areas, reference may be made to I. Schapera: "Economic Changes in South African Native Life," in Africa, I, 2; and to Monica Hunter: Reaction to Conquest, Chapters II and X.

usually in close proximity to some well-defined natural landmark, such as a hill, a stream, or the like; and these kraals are linked together politically as well as socially and geographically, forming a *ward* which will be described below. Wards tend to be separated from each other by relatively considerable distances; but they also tend to be grouped together in relative concentration in some given portion of the tribal territory, say on some particular side of a well-known boundary-line, such as a river or chain of hills. A number of wards, again, lying in the same portion of the tribal territory may, under certain conditions to be noted below, be linked together as a *tribal division*; and a number of such tribal divisions, or, failing the existence of these, a number of wards, make up a *tribe* and cover the territory which the tribe occupies.

A word may be said here as to the relation between the social and the political organisation of these peoples. Socially, they are divided into families, consisting of a man, his wife or wives, and their children; and families are grouped in clans (*isiduko, iziduko* *) consisting of all the descendants, in the male line, of a single ancestor. This division does not, however, necessarily coincide with the political division, as will be seen. Members of the same family may be spread over various kraals, wards, tribal divisions, and even tribes: and the same holds, *a fortiori*, in the case of clans. Conversely, the tribe, the tribal division, the ward, and even the kraal, may contain members of different families and clans. In one instance only does there appear to be coincidence between the political divisions and the social divisions, namely, in the organisation of the tribe for war, when definite clans are grouped together irrespective of their territorial organisation (*cf.* for the Gcaleka, the division into *Intshinga* and *Iqauka*, described in J. H. Soga: The Ama-Xosa: Life and Customs, p. 68). Otherwise the social and the political organisation appear to be independent cross-divisions.

We may now proceed to describe the various political units, their constitution and organisation, and the manner in which they are governed.

The Kraal.—The smallest political unit is the kraal (*umzi, imizi* †), which may be defined as a collection of huts occupied by a man, his wives, children, and dependants. The inhabitants of a kraal usually consist of people belonging to the same family or extended family; but members of other families only very loosely affiliated, and even entire strangers, may also be found in a kraal, though but rarely. This fact gives rise to

* *Isiduko* is defined by Kropf-Godfrey, *s.v.*, as (i) family name or honour; (ii) the name of the ancestor or stock from which a family or tribe is descended. From being applied to the name of the division, the word is also used of the division itself.

Xhosa nouns are given, when first cited, in the singular and in the plural.

† *Umzi* means "kraal, village," and (by extension) "family" (*i.e.* those inhabiting a kraal or village).

a fine theoretical distinction between the kraal as a social and as a political unit respectively. Socially, the inhabitants of a kraal may belong to different groups, and be subject to different authorities. Politically, there is no such distinction: all inhabitants of a kraal belong to the same political group and are subject to the same political authorities.

There is no need here to go into the constitution and arrangement of the kraal in detail. For our present purpose it is sufficient to remember one or two features which are of importance from the political aspect. Firstly, the kraal need not consist only of the huts belonging to a man and his various wives. His younger brothers may, even some time after their first marriage, live in the kraal with their wives and have huts there; and even comparative strangers may, especially nowadays, have huts in a man's kraal, rare though this may be. Secondly, a kraal may be divided up, one part being in one locality and another part in another, the parts other than that in which the Great Hut is situated being regarded as subsidiary.* All kraals, however, whether simple or composite, divided or undivided, form a political unit and are subject to a single political authority.

Kraals have their own proper names, derived usually from either the name of their founder or the name of some geographical landmark near which they are situated. Thus one kraal may be called *kwaPhoswayo* ("at Phoswayo's"), another *eMlanjeni* ("at the river").

The population of a kraal is variable in size. Some kraals contain only about ten or a dozen individuals, five or six adults and five or six children. Others may contain as many as twenty or thirty. The population of a ward depends on the number of kraals in it and on that of the population of each kraal, and runs from about a hundred to several hundreds. That of a tribal division varies extremely, some containing only a few hundred souls, others running into several thousand. The number of persons in a tribe is similarly variable. The following approximate figures, based upon official statistics (*cf.* N. J. v. Warmelo: The Bantu Tribes of South Africa), will indicate the position roughly in the three districts investigated:—

	Engcobo	Idutywa	Willowvale
Gcaleka . .	—	5573	8506
Mfengu . .	2717	4762	6585
Thembu . .	8821	225	—

The Kraal-head.—The general direction of the affairs of the kraal is in the hands of the kraal-head (*umninimzi*, *aɓaninimzi* ; *umnumzana*,

* Commoners rarely have subsidiary kraals, chiefs frequently. See, in the latter connection, the system of *iinkaɓi* described by Cook : Social Organisation and Ceremonial Institutions of the Bomvana, pp. 18 ff.

aɓanumzana *), who is responsible for the peace, order and good government of the kraal. Subsidiary kraals may often be a considerable distance away from the main kraal, and, in such cases, the kraal-head is usually represented at the subsidiary kraals by a deputy (*iɓamba, amaɓamba* †): and, if for any reason the kraal-head should be absent from his main kraal for any considerable length of time, he will be represented there also by a deputy.

The kraal-head is not appointed to the office, but establishes himself in it and is recognised in it by the members of the kraal, by the tribe generally, and by the chief. Inside the kraal, his functions are to supervise and to keep order and look after the interests of the kraal generally; and he has the power to adjudge in minor disputes between the inhabitants of the kraal, for whose conduct he is responsible to the various higher authorities.

Two ways exist in which a man may become head of a kraal: he may found it himself, or he may inherit it from his father. When a man dies, his senior male descendant becomes his successor; and this successor has sometimes to go back to his father's kraal to live and take charge there. The senior male descendant of the great house will usually, when he establishes his own kraal, place it fairly near that of his father; and, when the father dies, the son will sometimes move his own kraal to the site occupied by that of his late father. Sometimes, however, he leaves his own kraal where it was—or, at least, in part, bringing only his great wife with him—and either manages his own kraal himself from his new home or appoints a deputy if his own kraal is somewhat far away.

The Kraal-council.—The kraal-head is assisted in his duties by the other senior males in the kraal, such as his younger brothers beforementioned; and these, together with himself, form what may here be called a kraal-council (*iɓandla, amaɓandla* ‡). This council sits with the kraal-head to pronounce upon petty matters affecting the interests of the kraal only, such as cases of theft, quarrels between the inmates, disputes about stock, etc. Appeal lies from this council and from the decisions of the kraal-head acting alone or with its aid, to the next higher council

* Contracted from *umnini womzi*, "master of a/the kraal," in the case of *umninimzi*, and from *umnini womzana*, "master of a/the little kraal," in the case of *umnumzana*. As close compounds, *umninimzi* and *umnumzana* form their plurals by a change in the prefix of the first component only. The form *aɓanini ɓemizi* "masters of (various) kraals" is the plural, not of *umninimzi* but of *umnini wemizi*, "master of (various) kraals." *Umnumzana* is more generally used than *umninimzi*, except among the tribes dealt with in this paper.

† *Iɓamba* is derived from the verb *-ɓamba*, "hold, manage, rule."

‡ *Iɓandla* has various meanings, *inter alia*, that of "council" in which it is here used. The kraal-council is sometimes distinguished as *iɓandla lomzi*, "the council of the kraal."

and its presiding officer, described below. Like the kraal-head, the persons having a seat on the kraal-council are not formally appointed, but are recognised as being entitled to take part in the discussion of and decisions upon kraal affairs. In their official capacity as such they may be referred to as *amadoda eɓandla* (*lomzi*).* Sometimes the kraal-council will be enlarged temporarily by the addition of men from other kraals, whom the kraal-head calls in to help decide on a matter presenting some difficulty, in the hope of preventing an appeal from the decision of the kraal-council.

The Ward.—Several independent kraals, each under its own kraal-head, may be banded together under the jurisdiction of the kraal-head in charge of the chief kraal in the group. Such a group is best called here a ward, and is known as *ilali, amalali* † or sometimes as *isithili, izithili.*‡ Unlike the kraal, which is a purely natural unit and only incidentally a political one, the ward is to a certain degree an artificial unit, and in any case a fully-fledged political one. The ward may be regarded as something created for administrative convenience by the central authority, and contains diverse elements of population, not necessarily bound together by any social ties. Its head, as will be seen, is appointed from above, and does not succeed from below as of right; and, while the kraal is primarily a social unit, and only in the second place a political one, the ward functions primarily as a political unit.

Wards, like kraals, have proper names, which, like those of kraals, are derived either from the name of their founder (or sometimes from that of their present head), or from some geographical feature marking their locality.

The Ward-head.—The ward, as has been mentioned above, is under the jurisdiction of the head of the most important kraal in the group, and this official is known for this purpose as *isiɓonda, iziɓonda.*§ The ward-head, as we shall call him here, is usually a person of some rank as well, such as councillor (*umphakathi, amaphakathi* ‖) or petty chief (*inkosana, iinkosana*),¶ and is usually addressed by the title suitable to his

* *I.e.* "the men of the council (of the kraal)." The singular is *indoda yeɓandla* (*lomzi*).

† *Ilali* is derived by Kropf-Godfrey from the Dutch *laer*, and is used to indicate an encampment or village as well as a ward.

‡ *Isithili* is more often used to indicate a district or a region, as is also *ilali*. Its use to indicate a ward is rare.

§ *Isiɓonda* is here used figuratively. Literally it means "a pole or stake in a fence or hut" (Kropf-Godfrey, *s.v.*).

‖ The regular plural *aɓaphakathi* is also used, but is rare. The word means "one of the inner circle" and is derived from the adverbial noun *phakathi*, "in the middle."

¶ The diminutive of *inkosi*, "chief."

rank, in preference to the title of ward-head, which is only used when he has no other title, and was thought by the informants to be of recent origin in this sense. A ward-head, and even a simple kraal-head, may also, by courtesy, be known as chief (*inkosi, iinkosi* *).

Unlike the kraal-head, who is recognised as such but not appointed, the ward-head is appointed by the chief acting in consultation with his councillors and with the members of the ward. The ward-head is regarded, not as the ward's representative to the chief, but as the chief's representative in the ward, and is in that connection sometimes spoken of as the chief's "dog" (*inja, izinja*). The chief has, in theory, absolute power to appoint whom he will as ward-head; practically, however, this power is restricted in various ways. The person whom he appoints must be generally acceptable to the constituent kraals in the ward, and must belong to a relatively limited circle of persons who, by blood, or by their importance in one or other of the kraals in the ward, are entitled to claim appointment. Wards, and kraals within them, claim a considerable say in the appointment of ward-heads, and disputes arise when these claims are overlooked. In nearly all cases, therefore, a person already resident in the ward is appointed: and the position of ward-head tends to become a hereditary one, a man who is in the position being succeeded, on his death, by his senior male descendant living in the ward.

The functions and importance of a ward-head are to some extent determined by his status and personality and by the size and importance of his ward, though in all cases they are more purely political, and more important, than those of a kraal-head. Thus a ward-head who is in charge of a large and important ward, and who is a councillor or petty chief, can arrogate to himself a greater amount of authority than can a commoner in charge of a small and unimportant ward. The duties of a ward-head are both administrative and judicial. He is responsible for the peace, order and good government of the ward, and is generally in charge of its interests. As indicated before, also, he is the chief's representative in the ward, and carries out the chief's general policy and specific commands as affecting the ward. A large amount of his time is taken up by his judicial functions, since many petty cases come up to him on appeal from the kraal-council, and many more come up to him direct, as being too important to bring before the kraal-council even in the first instance.

The Ward-council.—The ward-head is assisted in his duties by the senior men in the ward, representative of the various kraals constituting it, usually from ten to twenty in number. All the kraal-heads, and a number of the other senior men, have this right and duty. In this function

* The term originally was used only of men of royal blood. But "nowadays, when chiefs have lost their authority, every man is *inkosi*" (Kropf-Godfrey, *s.v.*).

they are known either as *amadoda elali*,* or *amadoda eɓandla* (*lelali*),† or, by courtesy, as councillors (*amaphakathi*), and the ward-council which they form is known as *iɓandla* (*lelali*) ‡ or *inkundla* (*yelali*).§ Appeals lie, as has been mentioned, from the kraal-council to the ward-council, and it will be seen that, in turn, appeals lie from the ward-council to the chief's council. Ward-councillors are partly recognised, as in the case of kraal-heads who are automatically on such councils, and partly appointed, by the ward-head in consultation with his councillors and with the inhabitants of the ward. The office is also partly hereditary, son succeeding father, as is the case with ward-headships and membership of kraal-councils. The appointments are made by the ward-head acting for the chief, who in turn recognises and confirms them.

The ward-council meets outside the cattle-pen (*cf.* note § below). No statutory times exist for its meetings; but it is the duty of a ward-head to call a meeting of the ward-council whenever there is a sufficiency of business on hand to justify such action. The meeting is notified to the members of the council by messengers despatched by the ward-head; and it is made publicly known, though not, as far as could be ascertained, through the institution of the "town-crier," as practised, *e.g.*, by the Tswana-speaking tribes. Attendance at a meeting is compulsory for the members, and is not excused except for good cause shown, fines being levied for neglect of duty in this connection.

No meeting of a ward-council is considered valid without the presence, actual or by deputy, of the ward-head. If the members of a ward-council are at loggerheads with the ward-head, they may proceed to hold a meeting in his absence and without his knowledge or consent; but such meetings are considered irregular, and are in intent subversive of the ward-head's authority.

The procedure at a meeting of a ward-council is considerably more formal than at a meeting of a kraal-council, and may be very briefly indicated. The ward-head is usually present himself; but if, through absence or illness, he cannot be there in person, he is represented by a deputy. Let us imagine that it is a case which is being tried. The plaintiff is asked by the presiding officer to state his case. He proceeds to do so, and is listened to in silence and without interruption. His witnesses are then called to give their statements. The same procedure is followed in the case of the defendant. When all these have had their say, they are cross-questioned

* *I.e.* "men of the ward"; the singular is *indoda yelali*.

† *I.e.* "men of the (ward)-council"; the singular is *indoda yeɓandla* (*lelali*).

‡ *I.e.* "(ward)-council." "Council" is only one of the meanings of *iɓandla*.

§ *I.e.* "(ward)-council." *Inkundla* is "the clean, well-trodden place before a cattle-fold, where councillors gather to judge" (Kropf-Godfrey, *s.v.*). By extension, it is used for the court which judges.

by the various members of the council, in any order they please. Usually both plaintiff and defendant are then allowed further opportunity of restating their case, and may be cross-questioned afresh. When everybody has been heard, the councillors proceed to give their opinion on the merits of the case, and to suggest what action should be taken. The councillors speak in inverse order of their importance, the youngest and least important speaking first, the oldest and most influential last. The opinions of the councillors are then formally notified to the ward-head, if he is present, or to his deputy, if he is absent: but, if the ward-head has been absent only temporarily, and has returned before the close of the case, report will be made to him. The ward-head, or, in his absence, the deputy, then proceeds to sum up the case, and to give judgment. This procedure is followed in all councils of whatever rank.

On occasions other than court-cases, the procedure is somewhat modified. If, for instance, it is necessary to lay some matter before the people for their information and consideration, it has to be discussed first in the council. It is brought forward either by the chief or by his chief councillor, and is then discussed by all the other councillors who may feel called upon to express an opinion on the matter—again in the same inverse order of age and rank and importance in the council. When the matter has been thoroughly discussed in single set speeches, a period of informal debate may set in, with questions and cross-questions, interruptions, etc. After this, proceedings become more formal again, and the chief finally sums up the debate, and decides for the action proposed by the side which has the majority, or which, in his view, has taken the proper attitude on the matter.

The Tribal Division.—The next greater political unit is the tribal division, occupying what may here be called the district. By these two terms we must understand respectively a division of a tribe under the rule of a minor chief, and the area occupied by such division. The tribal divisions have their origins in various ways: they may be the followers of minor houses of the main line of chiefs of an originally integral tribe, who have hived off from the major body of the tribe in course of time and established a semi-independent identity of their own: or they may be the remnants of other tribes which formerly occupied the area, still retaining a form of semi-independence. It would appear that these divisions correspond to what has been described by Cook for the Bomvana, under the name *umhlaɓa, imihlaɓa.** It is difficult, however, to ascertain whether in the minds of the informants there existed any clear differentiation between

* Cook: *op. cit.*, p. 11 and elsewhere. Kropf-Godfrey, *s.v.*, give, as the only meaning of *umhlaɓa*, "the earth, the land, in opposition to the sea; the soil, ground." Tribal divisions and their districts must not be confused with the *iinkaɓi* described by Cook (pp. 18 ff.).

the tribal division and the area occupied by it on the one hand, and the tribe and its territory on the other; nor did there appear to be any specific terms in use to designate the tribal division and its district respectively. Some informants maintained that the term *isizwe, izizwe,* "tribe," could be used also to designate the tribal division; but others maintained that it could not be, though failing to name a term which could. Similarly, the term *umhlaɓa* was loosely used to designate the district occupied by a tribal division; but it was also used, even more loosely, to denote any tract of land occupied by a group of people, whether or not constituting a tribal division. The term *isithili* was also sometimes used to denote the district occupied by the tribal division, though it was usually applied rather to the ward, as described above.

The type of relationship existing between the tribal division and the tribe varies considerably. In some cases it is a very close one, in others extremely loose. Some tribal divisions are definitely subordinate to the tribe of which they form a part, and are under the authority of its chief and its governmental machine generally; others are virtually independent, and, except for a friendly interchange of symbolic ceremonial courtesies, have few relations with the larger body. The latter is the case particularly in relation to foreign elements living within the tribe's domain, and not themselves or through their line of chiefs related by blood with the main tribe. Such alien enclaves will, in a loose way, recognise the superiority of the greater body and own a certain measure of allegiance to its chief, expressed in the form of periodical tributes, consultations on difficult points of law or administration, and so forth. On the whole, however, the main tribe exercises little active authority over such subsidiary tribes, and, when it attempts to do so, disputes arise, showing that the authority is not fully and actively recognised. Tribal divisions which are related by blood to the larger body do, however, usually stand under the active control of the larger tribe and its chief, and recognise the authority exercised over them.

The type of relationship existing between the tribal division and the tribe is further illustrated by the names by which the people composing a tribal division call themselves. Tribal divisions, like kraals, wards and tribes, have proper names of their own—the names of tribal divisions, like those of tribes, being usually derived from the traditional founders of such divisions. Thus the *AmaVelelo,* a division of the Gcaleka tribe, are called after Velelo, who founded the division and gave it semi-independence. Now when the relations between the tribal division and the main tribe are close, the members of the former call themselves by the name of the main tribe as well as by that of their own proper division: thus the AmaVelelo often refer to themselves as AmaGcaleka. On the other hand, when the

relations are somewhat distant, the members of a tribal division will not readily adopt the name of the main tribe. Thus the *AmaNtinde*, the members of a division of the Gcaleka tribe founded before the latter had attained its own individuality, do not usually refer to themselves as *AmaGcaleka* as well, though nowadays they tend to do so in a loose way.

The Minor Chief.—At the head of the tribal division stands the minor chief (*inkosi*), so called here in contradistinction to the paramount chief over the tribe, to be dealt with later. The minor chief succeeds to his office in the same way as the paramount chief, as will be described below, and exercises over his division and over the district occupied by it the same rights as the paramount chief does over his particular section of the larger tribe. Often such minor chiefs are descendants of a minor house in the line of the paramount chief, and sometimes they are descendants of an unrelated line, as in the case of the more or less subjugated alien enclaves which have been mentioned above. If fairly close relations exist between the tribal division and the main tribe, minor chiefs will derive a certain amount of authority from, and own a certain measure of responsibility towards, the paramount chief: if this is not the case, they are virtually autonomous within their own tribal division.

The Tribal Division Council.—The minor chief is assisted by the tribal division council (*iɓandla* (*lomhlaɓa* or *lasebotwe*): *inkundla* (*yomhlaɓa* or *yasebotwe* *)) consisting of councillors (*amaphakathi*) usually from ten to twenty in number. One of these councillors, who is the chief's right-hand man, is known as *induna*, *iinduna* or *umphakathi omkhulu*, *amaphakathi amakhulu*.† In addition to the council proper, there is a kind of inner circle or privy council (*igqugula*, *amagqugula*); and, in addition to the councillors proper, there is a class of men who may here for convenience be called remembrancers, whose duty it is to give the council advice on points of law and matters of precedent, and who are called *inyange*, *amanyange*.‡ Further, there is a body, consisting of all the male members of the tribal division who have kraals of their own or who occupy senior positions in kraals in which they live. This body may be called the tribal division

* *I.e.* "(district) council" and "council (of the Great Place)" respectively, either *iɓandla* or *inkundla* being used in this sense. For the meaning of *umhlaɓa* cf. what has been said above. *Lasebotwe* is the possessive formed from the locative of *ibotwe*, *amabotwe*, "Great Place" in the accepted sense. For other meanings of *ibotwe*, cf. Kropf-Godfrey, *s.v.*

† *Induna* means, *inter alia*, "chief councillor or minister of the chief" (Kropf-Godfrey, *s.v.*, where the other meanings of *induna* should also be compared). *Umphakathi omkhulu* means "great councillor."

‡ Kropf-Godfrey give only the plural form *amanyange*, with the meaning "the people of old; elders, ancestors." But the word was used by informants in the singular as well, and with the meaning given above.

meeting, and is known as *imbizo, iimbizo.** The constitution, manner of appointment and functions of these bodies and persons respectively in the tribal division correspond to those of similar bodies and persons in the larger tribe, and will be treated of in detail below. It will only be necessary to mention here that in all cases the authority of the tribal division—as expressed in its chief, privy council, council, and full meeting—forms the next higher instance of appeal from the authority of the wards comprised therein, and that the tribe is generally the next higher legislative, executive, administrative, and judicial unit for all purposes. In cases where close relations exist between the tribal division and the main tribe, the latter and its centrally organised authority form the last instance and are the final administrative body to which appeals may lie and which runs the ultimate administration of all the tribal divisions comprised within it and owning its authority. If the relations between a tribal division and the main tribe are tenuous, the tribal division considers itself as the final administrative and judicial authority, and is generally left undisturbed in this regard by the main tribe.

The Tribe.—The largest political unit is the tribe (*isizwe, izizwe* †), which consists of all the people who own ultimate allegiance to a paramount chief, either directly, or, more usually, indirectly through minor chiefs subordinate to him and controlling tribal divisions. It is usually made up of a number of such divisions, loosely or firmly knit together in the way discussed previously, though very small tribes may exist which are not subdivided in this manner. When there is more than one division, the major division, usually consisting of the main body of tribesmen, and regarded as the main tribe, is usually under the direct rule of the paramount chief, who, in this connection, may be regarded as only the greatest of the minor chiefs in charge of tribal divisions, his function as paramount chief being with reference to the whole rather than to this one particular part. The area occupied by a tribe, which will here be called its territory, bears various names. Usually it is known as *ilizwe, amazwe* ‡; sometimes it is loosely spoken of as *umhlaɓa*, the term also used equally loosely to indicate

* *Imbizo*, with the alternative form *imbiza*, is given by Kropf-Godfrey as "a convened meeting, after the analogy of Sesuto *pitso*, from *pitsa*" (read *bitsa*). It is interesting that the word should have been formed on the analogy of a foreign one, and it may be that this points to the fact that the thing denoted was formed, or its function extended, under the same influence. It will be seen below that the *imbizo* does not play the same important part among the Xhosa-speaking tribes here investigated as it does among the Sotho-speaking tribes.

† *Isizwe* is defined by Kropf-Godfrey as "a tribe, clan, nation, people." The inclusion of "clan" in this definition seems erroneous. The root *-zwe* is the same as that of *ilizwe*, "country."

‡ *Ilizwe* is also found in the contracted form *iizwe*, written *izwe*.

the area occupied by the tribal division; and sometimes it has applied to it the word *ummandla, imimandla.** *Ummandla*, however, is also used to indicate, not so much the area occupied by the tribe as the dominion exercised by the chief over his people; and, in this connection, it may be as well to draw attention to an interesting dualism pervading Xhosa, and generally Bantu, conceptions with regard to the chief's jurisdiction. On the one hand this jurisdiction is regarded from the personal aspect, since all tribesmen owning allegiance to a chief are reckoned as being his subjects and as living in his *ummandla*, no matter how dispersed the territory of the tribe may be or where, temporarily, its members may happen to live. On the other hand, the chief's jurisdiction seems to be regarded also from the territorial aspect, since all those living in the area over which he exercises control are reckoned as his subjects, no matter what other allegiance they may have owned or feel they still own.

Tribes have proper names, derived in various ways, but usually from the name of their traditional founder, e.g. *AmaGcaleka* from Gcaleka, *AбaThembu* from Thembu. They change their names as they change their status: so, for instance, both the Gcaleka and the Ngqika ("Gaika") tribes were at one time called only *AmaXhosa*, after Xhosa, the legendary founder of the undifferentiated tribe. But when the present Gcaleka and Ngqika tribes acquired their independence and hived off from the main tribe, they took the names of their own more immediate founders.

The Paramount Chief.—At the head of the tribe stands the chief (*inkosi*), here called the paramount chief to distinguish him from the minor chiefs of tribal divisions, and in Xhosa nowadays often referred to as *inkosi enkulu*, "great chief," for the same reason. As will be clear from what has gone before, the term "paramount" as here used must not be interpreted too honorifically, as the paramountcy referred to may often be but a tenuous thing. The position of chief, whether minor or paramount, is, as generally among the Southern Bantu, a hereditary one, and the manner in which a man succeeds to the chieftainship is according to the general Nguni pattern. A few of the salient points in this pattern may be recapitulated here; but this will need to be but briefly done, as it has been frequently described in the extant literature on the Xhosa-speaking tribes.

A kraal, whether that of a chief or that of a commoner, consists of "houses" or hut-groups, the individual huts in each house and the houses in the kraal being related to each other in a manner which we shall note presently. For the sake of clearness, we shall employ the word "hut" only to designate the individual structure occupied by a wife and her children, and reserve the term "house" for the hut-group whose nature

* *Ummandla* has as stem an abbreviated form of the noun *amandla*, "strength."

will emerge below.* A house, then, consists of a principal hut and one or more supporting huts, attached to the principal hut for the purpose mainly of producing sons in case the principal hut should fail to do this. Commoners, especially the younger and poorer ones, may have only the principal hut in each house, and may have only one house: mostly, however, they have supporting huts in the houses, and two houses in a kraal. Chiefs usually have a number of supporting huts in each house, and usually three houses, though formerly they had four. The four houses are:—

(*a*) The great house (*indlu enkulu* †) consisting of the great hut with its supporting huts.
(*b*) The right-hand house (*indlu yasekunene* ‡) consisting of the principal right-hand hut with its supporting huts.
(*c*) The left-hand house (*indlu yasekhohlo* §) consisting of the principal left-hand hut with its supporting huts. This house appears to be obsolete at the present time, but it was formerly in evidence, especially among chiefs.||
(*d*) The ancestral house (*ixhiɓa, amaxhiɓa, or indlu yasexhiɓeni* ¶) consisting of the principal ancestral hut with its supporting huts: this house is one founded, usually by a chief only, at his late father's kraal.

The wives in the principal huts in the various houses are spoken of respectively as *umfazi wendlu enkulu, umfazi wendlu yasekunene, umfazi wendlu yasekhohlo*, and *umfazi wendlu yasexhiɓeni*.** The wives in the

* In Xhosa, however, no such distinction is made, the word *indlu, izindlu* (with the alternative plural *iindlu*) being employed in both senses; and hitherto in the literature the same confusing ambiguity in nomenclature has prevailed. The term "house" is often used in the sense of "principal hut" as here employed, and leads to confusion. Very often one is at a loss to know whether, *e.g.*, "Great House" as so used means the house in the sense here understood, or only the principal hut in the house.

† Often contracted to *indlwenkulu, indlunkulu*.

‡ *Yasekunene*, literally "of at the right-hand side," is a possessive formed from the locative of *ukunene*, "the right side."

§ *Yasekhohlo* is a possessive formed from the locative of *ikhohlo*, "the left-hand side."

|| Or, according to some informants, only among chiefs, *cf.* Cook, *op. cit.*, p. 15. The left-hand house is still extant among the Zulu, where it is known as *indlu yasekhohlo* or *yasekhohlwa*.

¶ *Ixhiɓa* is defined by Kropf-Godfrey as "the great house of a deceased chief." *Yasexhiɓeni* is a possessive formed from the locative of *ixhiɓa*. The Mfengu use the term *isizinde, izizinde* (*cf.* Zulu *isizinda*).

** The great wife alone is properly spoken of as *inkosikazi, amakhosikazi*; but this term is now used to designate women of quite inferior rank as well. To the great wife, as well as to the various other principal wives in the houses, a number of specific forms of address are employed which need not be detailed here.

supporting huts are called *iqadi, amaqadi,** and the term applied to them is also sometimes loosely used of their huts.

The principal wives in each house rank according to the order of their houses as given above, *i.e.* the great wife ranks first and the principal right-hand wife second. The principal left-hand wife would rank third if, as among the Zulu, the institution of the left-hand house still existed. The principal wife of the ancestral house falls outside this ranking. The supporting wives of the various houses rank according to the chronological order of their marriage, and we may note that, among commoners, the first wife married is the great wife, the second the principal right-hand wife, the third the first supporting wife of the great house, the fourth the first supporting wife of the right-hand house, and so on, supporting wives of the great and right-hand houses being married alternately. Among chiefs, this order is to some extent broken. The great house is seldom if ever founded first, and the first wife married is seldom if ever the great wife. The great wife of a chief, unlike his other wives, is ***loɓola***'d with cattle subscribed by the tribe, and this is done when he is already chief, and has, in most cases, already several wives. But, whatever the chronological order of the founding of the great house of a chief, it ranks first, and the great wife ranks first whatever the chronological order of her marriage.†

This arrangement and ranking of houses and the status of the various wives in each house, especially the position of the great house *vis-à-vis* the other houses, and the position of the various supporting huts of each house relative to each other and to their house, are of prime importance for the involved laws of succession prevailing among the Xhosa-speaking tribes. The following may, perhaps, serve as a simplified statement of these laws in their most generalised form:—

(*a*) Succession passes to the great house. The right-hand house has no part in succession unless the great house cannot produce a successor.

(*b*) The senior surviving male descendant in the great hut succeeds, and, failing him, the senior surviving male descendant in the senior supporting hut of the great house, or in the next senior supporting hut of the great house having male issue. Such son from a supporting hut will be, as the Xhosa phrase has it, "put into" (*-ɓekwa* ‡) the great hut for the purpose.

(*c*) If the great house cannot produce a successor at the time required,

* *Iqadi* has the same stem as *umqadi*, "the principal, uppermost rafter of a roof or house, lying across the poles which are used as pillars" (Kropf-Godfrey, *s.v.*). The supporting wife is thus regarded as a "rafter" of the principal wife's hut.

† The final status of the wives previously married is determined after the marriage of the great wife according to rules and by arrangements which need not be detailed here. They are usually ranked as supporting wives of the great and right-hand houses.

‡ The passive form of *-ɓeka*, "put, place."

i.e. if there is no male issue living in the great house at the time when the previous chief dies, a fresh wife is *loɓola*'d for the great house. This woman is taken as a supporting wife to the great house, and is expected to produce male issue for it. A man of the proper status (usually the previous chief's next younger brother) will "go in to" (*-ngena* *) her and raise up seed by her to the great house.

(*d*) If the great house fails to produce a successor at all, succession may pass to the right-hand house, along the same lines as in the great house.

It may be remarked in passing here that the third and fourth rules are seldom applied—the third rarely, the fourth hardly ever. Investigation of the details of tribal history shows that the principal hut in the great hut usually does produce a successor, and that, when it fails to do so, it seldom happens that there is no son available in one of the minor huts of the great house who can be put into the great hut in the manner indicated.

Considerable attention is paid to the pre-nuptial status of the woman taken as great wife, and to that of those taken as senior supporting wives in the great house, and also, should the case arise, to the status of the man appointed to raise up seed to the great house. This flows from the general desire that the future chief shall have, if possible, only chiefly blood in his veins, on his mother's as well as on his father's side. Among even small and unimportant tribes it is therefore thought highly desirable that the woman taken as great wife should come of a chiefly family, while among large and important tribes this is considered essential. Similarly, even among small tribes of little importance, it is considered desirable that the senior supporting wives of the great house should be of chiefly stock, while in the large tribes of importance this is the rule. As the tribe always furnishes the *ikhazi* † or bride-price of the great wife, and sometimes contributes to that of some of the senior supporting wives of the great house, it has a considerable say in the selection of the great wife and sometimes in that of the senior supporting wives; but this say is limited, *inter alia*, by its resources, since the bride-price increases in size with the status of the woman's *loɓola*'d, and the tribe must be content with a woman whose status is proportionate to the size of the bride-price which it can afford to pay. The selection of the man appointed to raise up seed to the great house usually offers little difficulty, since the previous chief is bound to have left one or more living younger brothers capable of performing this duty.

* *-Ngena* is given by Kropf-Godfrey as occurring (in Mbo only) with the meaning "to marry or carnally know one's late brother's wife." The restriction to the late brother's wife seems erroneous in this definition; and the word is used in the broader sense given here, as well as in the restricted sense, in dialects other than Mbo.

† Plural *amakhazi*.

Should the successor be a minor at the time of his succession, a regent (*iɓamba* *) is appointed by the tribal council subject to the cognizance of the tribal meeting, to hold office until the successor's majority. This regent, while in office, has all the powers and privileges, and performs all the duties and obligations, of the chief. He is expected to lay down office when the minor has attained his majority, *i.e.* when he has taken his first wife. As there is no statutory age at which this happens, and as the regent cannot be legally forced to relinquish his office even then, a regency may last a very long time, and may be unconscionably prolonged by an ambitious regent eager to cling to the sweets of office. On the whole, the number of cases in which this sort of thing occurs is not large; but cases are not wanting, and, when they do arise, they lead to bitter disputes and tribal factions. Reference may here be made to the well-known dispute between Ndlambe and Ngqika, described, *inter alia*, by Sogá.†

The person appointed as regent is usually the next younger brother of the previous chief, or some other senior male next in the order of succession in the indirect line. Failing all possible males, the great wife, or whoever is the legal mother of the successor, will be appointed regent for her son. Such cases are of course extremely rare. When they do occur, the woman does not, otherwise than in exceptional cases, play her part as ruler very actively. She is assisted by the tribal council, as the chief is, and the chief councillor will be her right-hand man, and will become, in effect, the regent.

Two possible cases of succession to chieftainship remain to be considered: the first, when neither the great house nor the right-hand house is able to produce a successor, *i.e.* when the line of chiefs dies out; the second, when chieftainship passes from one family to another by force. The first of these is extremely rare, and informants were only able to relate what the theoretical possibilities were likely to be in such a case. It was stated that, when a line of chiefs had completely died out, the tribe would proceed to elect a new chief. No instances were given when this had actually happened. The second case, that of chieftainship being wrested from one family by another, was of only slightly more frequent occurrence. Usually, in such cases, the contending families would form two factions, one remaining with the chief whose chieftainship had been wrested from him, and recognising his successors as their chiefs. Sometimes, however, a whole tribe might go over, in a body, to a pretender to the chieftainship, and the previous chief would be deposed and his successors remain bereft of their inheritance. Such cases, again, were so rare that no actual example could be cited by the informants, who could only speak theoretically.

* The same word as is used of a representative.

† J. H. Soga: The South-Eastern Bantu, chap. xiii, pp. 148 ff.

The chief has many functions, powers, privileges, duties and obligations of a non-political as well as of a political nature. Of the former it will not be necessary to speak here at all, except to mention them summarily. Besides being generally the father of his people, in the sense of being responsible for their general welfare and having control over their general affairs, the chief is specifically their religious, economic and military head, as well as being their supreme administrative and judicial authority, which makes him responsible respectively for the due performance of all tribal religious acts (such as the worship of the tribal ancestors, first-fruits ceremonies, etc.), for the regulation of the economic life of the tribe (such as the apportionment of land and the regulation of the agricultural year), and for the conduct of military campaigns (now, except for petty faction-fights, a thing of the past). As regards the chief's political functions, no detailed description will be attempted, firstly, because these are well described in the extant literature on the Xhosa-speaking tribes generally, and because these, in the tribes dealt with here, differ little if at all from the general picture given in the literature; and, secondly, because sufficient indication has been given, in dealing with the kraal-heads, ward-heads, and minor chiefs, as to what chiefly office implies. It will only be necessary here to say, by way of summary, that the chief is the ultimate legislative, executive, administrative and judicial authority of the tribe, and the repository of its political will, which is concentrated in him and expresses itself through him in the exercise of his various functions. In theory he is, according to all informants, an absolute ruler: but this statement is always qualified by adding that he must rule according to the law of the tribe, and that he is not above the law. And indeed, in practice, this is the case, apart from exceptions which, however, are relatively few. Chiefs are held in great regard, and their will is greatly respected; but they are not allowed to go beyond certain limits in the exercise of their will, and are speedily and effectively checked if they exceed such limits. They will be told, respectfully but firmly, that the council and the tribe are unwilling to obey their commands. If a chief persists, an effort may be made to depose him; and, if this latter fails, the discontented tribe or section will leave him, hiving off to found a tribe of their own with a chief more amenable to their wishes.

The Tribal Council.—The paramount chief is assisted in his functions by various bodies and persons, the most important of which is the tribal council (*iɓandla* (*lelizwe, lesizwe, lasebotwe*); *inkundla* (*yelizwe, yesizwe, yasebotwe**)). This is made up in the same way as tribal division councils, ward-councils, and kraal-councils, but is somewhat larger, from twenty to

* Both these sets of expressions mean "council (of the country, of the tribe, of the Great Place)."

thirty in number. In theory, it consists of the paramount chief himself and of the minor chiefs of tribal divisions together with the senior male members of the chief's family, who usually are, but need not necessarily be, minor chiefs of tribal divisions or ward-heads; and to these may be added heads of large and important wards, an occasional old and influential head of a large and important kraal, and, more particularly in recent times, some comparatively young men of little importance except such as derives from the fact of their being personal friends of the chief, and of having received some measure of European education and gained some experience of life among Europeans. In theory, the chief chooses his council: in practice, he is limited in his choice, since the claims of blood and status in the tribe help to determine for him pretty much whom he shall choose. A large proportion of the personnel of a tribal council holds office by hereditary right, while only relatively few have seats by virtue of their personality. In theory, again, councillors hold office during the chief's pleasure; and in practice the chief can and does sometimes depose councillors whom he has appointed by virtue of their personality and influence with him, but who have lost his favour. But it is seldom that he can venture to depose a councillor who is such by right of hereditary claim or social status, though, if he wishes it, he can pay little heed to the opinions and wishes of such a person.

In theory, the tribal council is only an advisory body to assist the chief in coming to a decision, and an auxiliary body to help him carry out his wishes. The form in which decisions are taken is illustrative of this theory. Each councillor, usually beginning with the youngest and least important, and ending with the oldest and most powerful, has his say. Their opinions are communicated by the chief councillor to the chief, who may not even have been present when they were being expressed; and the chief sums up what has been said, and gives his own opinion of the matter, which becomes his decision. It would appear, then, that the chief is not bound to take the advice of his councillors. In actual practice, however, it happens but seldom that his opinion is not based upon a sort of mean of the opinions expressed by the various councillors. It may be that the chief takes sides with one set of opinions rather than with another, if there are contending views; and in such case the side he opposes may be dissatisfied with his action. But it will submit, and recognise the right of the chief to follow one set of opinions rather than another in making up his mind. If the whole of a council were to be of one opinion, however, the chief would in practice not venture to run counter to it. Informants were quite at a loss to state what would happen if a deadlock of this kind were reached; they could not imagine such a thing happening as that the chief would persist in differing from all his councillors.

In fact, then, though in theory the chief is the supreme authority, the tribal council is the ultimate executive authority as well as the ultimate judicial court of appeal. But it is not purely self-contained; and we must proceed to examine three sources from which its decision are influenced—leaving out of account for the moment the chief's influence, which we have already touched upon—and one mechanism for reviewing its decisions.

The Privy Council.—A chief usually has attached to him a small and select group of men, consisting of a few of his most powerful and intimate councillors, who form what will here be called the privy council (*igqugula, amagqugula* *). This body sits with the chief in secret, both before and, if necessary, during and after meetings of the tribal council, to prepare matters for submission to the council, to determine lines of policy in presentation and putting-through, and generally to act as a sort of inner official caucus of the council. It is, of course, extremely influential in the council, and the latter usually passes substantially what the former has decided upon previously. The members of the privy council are, naturally, chosen by the chief, and do not have seats as of right; nor are the appointments formally made. The decisions are also not made public.

The Remembrancers.—Outside the council proper, there is a class of men (*inyange, amanyange*) here called remembrancers, who may or may not be members of the council, but who materially assist the latter in coming to its decisions. They are chosen for their knowledge of tribal law and precedent, usually on account of their age, their interest in and their memory of such matters; and it is their duty to tender to the council, when called upon to do so, advice on matters of law, of precedent, and of the facts involved and the arguments used in former cases, in order that the council may take the proper decision upon the specific matter in hand. These men, as such, have no direct voice in the deliberations or decisions of the council; but their indirect influence upon such decisions is considerable.

The Chief Councillor.—A councillor, in his function as such, whatever be his other titles, is known as *umphakathi*, and one such, who is the chief's right-hand man and most important councillor, is known as *induna* or *umphakathi omkhulu*. This latter officer is a most important person in the tribe generally and in the council in particular. His duties are to act as intermediary between the chief and the council, the tribe, and others. To him all matters are reported for transmission to the chief, he has first notice of any case which has to be tried or any project which has to be discussed, he settles the order in which things are brought before the chief

* *Igqugula* is defined by Kropf-Godfrey, *s.v.*, as "secret council of a chief with his councillors; secret consultation; a commission," and is derived from the verb-stem *-gqugula*, "to consult together privately, take secret counsel together."

and the council, and he has considerable influence in the discussion and the decision upon such matters, besides determining, very largely, the speed with which things are handled. He is chosen and appointed by the chief, who may, in theory, appoint whom he likes. In practice, the chief's senior paternal uncle is usually chosen, though especially nowadays a younger man with a European education and a knowledge of European ways may be selected; but the tendency is to adhere to the person who has claims of blood and status. The office tends to be hereditary: should the chief councillor die, his son, if old and important enough, has a strong claim to be chosen to replace him. On the accession of a new chief, such chief councillor may, in theory, be replaced like other councillors: in practice, he is not replaced any more than they are.

The manner of summoning a tribal council, the importance attached to attendance at its meetings, the validity of its meetings and decisions, and the procedure followed, are the same as have been described in the case of the ward-council.

The Tribal Meeting.—Having noticed the privy council and the remembrancers, and having made brief mention of the chief councillor, it remains to notice the tribal meeting (*imbizo*). This is a meeting of all the adult male members of the tribe who have kraals of their own or who occupy important positions in the kraals in which they live. It is called together to hear and discuss questions of general importance and great moment to the tribe as a whole. In theory, a decision taken upon such a point by the tribal council is subject to revision, if necessary, by the tribal meeting. Actually, such revision seldom if ever takes place. The tribal meeting is too large a body to permit of effective discussions, and as no vote is taken upon matters brought forward, its function reduces itself to the formal and rather passive cognizance which is taken of decisions already reached by the smaller body. The existence of the tribal meeting is, however, a proof, if any were wanted, of the essentially democratic nature of Xhosa government—at least in theory. The tribal meeting is the gathering of the largest possible number of people whose voice counts at all in the management of tribal affairs: and the fact that it is called upon to take cognizance, however passively, of the decisions of the smaller bodies in which the will of the people is concentrated and through which this will is expressed, shows that, in theory, the people does not entirely delegate its deliberative, legislative and executive power to such bodies, but reserves the right to take cognizance of what has been done, and, in extreme cases, to review and rescind. It may be mentioned here, finally, that the tribal meeting is not called as frequently, nor does it function so actively, as is the case among the Sotho-speaking tribes with their corresponding *pitsô*; and it may well be that, just as the Xhosa word *imbizo* is probably coined on the

analogy of the Sotho word *pitsô*, so the Xhosa body is formed and functions on the analogy of the Sotho body, and that the tribal meeting does not belong as integrally to the Xhosa political system as it does to that of the Sotho-speaking peoples. Tribal meetings are called frequently among the latter, and have a very definite and powerful say in the management of tribal affairs. Among the Xhosa-speaking peoples they are infrequently called, and their voice in the management of the tribe's affairs is not to be compared for effectiveness with that allowed by the Sotho system. In former times, when war was still a living thing in tribal life, it appears to have had considerable say in determining whether the tribe should go to war or not; nowadays, this function does not need to be fulfilled, and the rôle of the tribal meeting appears to have become reduced to providing a public background for the reception of the decisions of the tribal council, and for the entertainment of distinguished visitors.

ANOMALOUS SECONDARY THICKENING IN *OSTEOSPERMUM*.

By R. S. Adamson.

(With eight Text-figures.)

(Read September 16, 1936.)

The genus *Osteospermum* contains a number of species of which some are common and widespread plants in South Africa. One of the commonest, *O. moniliferum*, shows anomalous secondary thickening in the stem and root. The anomaly was discovered when the plant was employed as a type for showing anatomical structure for elementary classes. In the younger stages the structure is normal and approximates closely to that in *Helianthus*, but in the second and subsequent years anomalies appear.

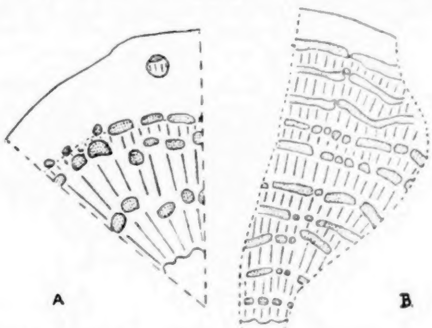


Fig. 1.—*O. moniliferum*. Outlines of sections of stems showing successive zones of secondary tissues. A, ×6; B, ×8.
Phloem, dotted; xylem, lines.

O. moniliferum is a shrub growing most commonly on sand. It may attain a height of 4–6 feet (1·5–2 mm.), and the main stem may be as much as 1 inch (92·5 cm.) in diameter. In loose soils the plant spreads by suckers from horizontally growing roots. The suckers may appear many yards from the parent plant.

Structure.

Stem.—During the first year the structure is normal: a ring of wood traversed by rather broad medullary rays is formed. The activity of the

cambium ceases altogether, or in part, at the end of the first year, and further growth is from one arising by division of cells immediately external to the phloem and inside the small strands of pericycle fibres. Additions of secondary tissues are formed by the pericyclic cambium in the ordinary way, and are exactly like those formed by the original cambium. The whole of the first cambium may cease activity, or the fascicular portions stop while the interfascicular parts continue. In the latter case a "Bignonia" structure results. An old stem where this occurs shows isolated strands of phloem surrounded by xylem. In the subsequent growth the

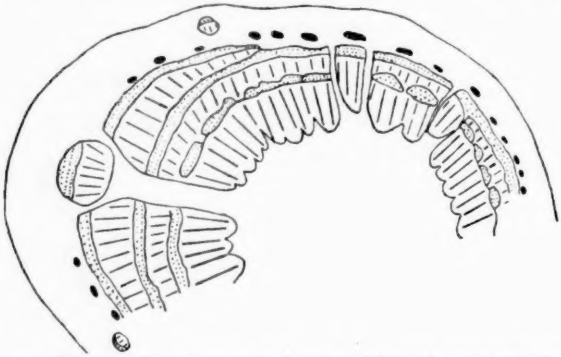


FIG. 2.—*O. moniliferum.* Section at node showing additional zone at the branch side. × 10.

whole cambium ceases activity and the new tissues are formed as concentric rings. Each pericyclic cambium is active for one year and is then replaced by a new one.

Though the successive cambia are described as concentric, the axis is rarely symmetrical. A new cambium starts activity on one side before the other. The start of activity appears to be connected with leaf and branch traces. Three main strands enter each leaf, and these pass down the internode below before uniting with the cylinder. A new pericyclic cambium arises in relation to these bulging strands. Where a branch is formed there is very distinctly increased activity on that side; in extreme cases an additional zone of secondary tissue is laid down on the branch side before any trace of it is seen on the other one (fig. 2).

Formation of Pericyclic Cambia.—In the primary stem the pericycle is represented by strands of fibres with one or more layers of parenchyma internally. As phloem is added by the cambium the sieve tubes and companion cells of the primary strand become squashed, though the associated parenchyma persists and soon becomes indistinguishable from the parenchyma of the pericycle.

The cells of the secondary phloem, with the exception of the sieve tubes, become lignified. Lignification does not commence with the oldest cells, but, once started, progresses outwards and inwards. The change does not affect the parenchymatous cells of the primary strand. It is from these cells external to the lignified secondary phloem that the new cambium arises. Its first appearance (fig. 3, A) is seen in tangential division of cells just outside the lignified part of the phloem. Divisions usually commence

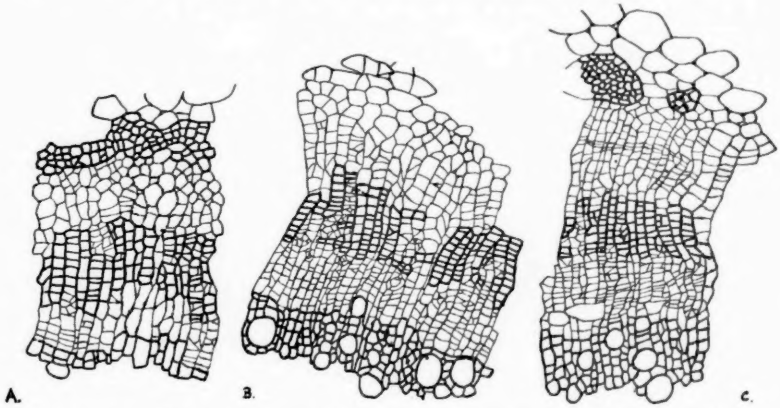


FIG. 3.—*O. moniliferum.* Successive stages in the formation of the pericyclic cambium. A, first division of cells outside the phloem; B, a later stage (the fibres are not shown); C, new cambium fully developed. The earlier cambium is still active. A, × 140; B and C, × 120.

at the sides of a bundle. A new cambium arises at the beginning of a season's growth (fig. 3, B); plants collected in August showed a distinct new cambium, whereas in July there was no sign of cell division. The new cambium may start the formation of secondary tissues even before the previous one has ceased (fig. 3, C); as a result, additions take place simultaneously at two levels, though this is not continued long. The pressure soon causes a stoppage of division in the inner one.

As successive cambia arise in this way the fibre strands become pushed further and further out. In the earlier stages successive cambia arise immediately outside the previous phleom, so that the zones of tissue are contiguous, or nearly so. In old stems there may be a zone of ground tissue between adjacent rings.

The underground portions of the stem only differ in having larger amounts of ground tissue between the zones and a smaller pith.

Root.—The root system consists of a tap root with a few strong branches. Numerous small thread-like roots which are not much branched arise from

the larger ones. In old plants long horizontally running roots are formed which penetrate the soil close to the surface, and from which suckers arise.

In structure roots show the same scheme as stems. In the early stage growth is normal; there are 3–5 protoxylem strands, less often 2 or as many as 6. In the main roots there are 3–4 protoxylems, which are close together and primary xylem forms across the centre, whereas in the lateral roots the number is greater, and a pith, which becomes lignified, is present. The cambium arises early. At first the addition of xylem is more rapid than that of phloem; phloem is generally only formed opposite to the strands of primary phloem. After a time the formation of xylem stops opposite to the phloems, but continues elsewhere and a "Bignonia" structure results. The cambium continues, and joins up external to the phloems; new phloem strands are formed externally. Soon, however, the whole cambium ceases activity and a new one is formed external to the new phloems, and subsequent growth proceeds exactly as in the stem. Successive zones in the root are most often separated from one another by ground tissue.

In some lateral roots a slightly different arrangement occurs. The "Bignonia" arrangement is not formed; phloem is added all round from the first. This gives a more regularly symmetrical arrangement. In the root the amount of lignification of the phloem is less than in the stem, it is confined to the outermost parts and the sides abutting on rays.

The suckers that arise from the horizontal roots arise from the cambium. The formation of the bud causes a great increase of activity in the formation of secondary tissues, and several additional rings occur on that side, all of which connect with the tissues of the shoot.

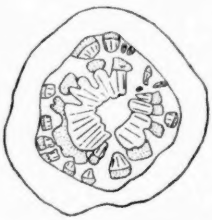
Other Species.

For comparison with *O. moniliferum* some other species of *Osteospermum* were examined. The following were those studied: *O. Burchellii*, *O. ciliatum*, *O. coriaceum*, *O. grandidentatum*, *O. ilicifolium*, *O. imbricatum*, *O. muricatum*, *O. polygaloides*, *O. spinosum*, *O. subauriculatum*, *O. subulatum*, and *O. trigonospermum*. In these species, with the exception of *O. ciliatum* and *O. subulatum*, the structure of the secondary tissues was normal. The material available in some of the plants was not extensive, and roots were examined in *O. ciliatum*, *O. ilicifolium*, and *O. spinosum* only. In the two last-named species a full examination was made that included old stems and roots, but no trace of anomalous structure was seen.

In the two species which show anomalous growth, *O. ciliatum* and *O. subulatum*, the general arrangement is the same as in *O. moniliferum*, though there are some differences in detail.

O. subulatum.—In the stem the fascicular cambium is alone active in the formation of secondary tissues, so that the first cylinder is made up of strands separated by rays; the cambium develops unequally and the cylinder is fluted. After the first season a pericyclic cambium arises, which lays down strands separated by broad rays. The new strands are not very regularly arranged, and a second new cambium may commence growth in parts while the previous one is still active (fig. 4).

O. ciliatum.—This is a more or less prostrate plant which is much



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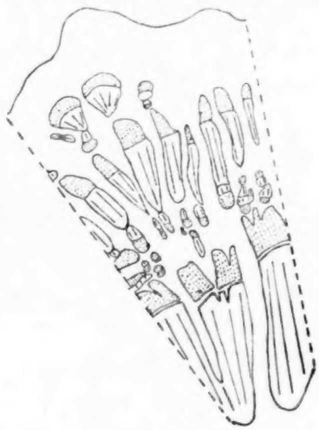

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FIG. 4.—*O. subulatum.* Section of stem showing anomalous strands. × 12.

FIG. 5.—*O. ciliatum.* Section of old stem showing anomalous secondary strands and reversed strands between the main zones. × 8.

branched. The distal parts of the branches die back annually, while the lower parts persist and give rise to new branches.

Stem.—The parts with limited duration have normal structure; it is only in the lower persistent portions that anomalous increase is seen. The plan of construction is like that of *O. moniliferum*, but the arrangement is less regular and there are some complications.

The original cambium persists for longer—generally for two seasons. The wood formed may show concentric zonation; the last-formed part has thin-walled cells in the rays. At the cessation of cambial activity the xylem cylinder is distinctly fluted.

The tissues formed by the pericyclic cambia are in strands separated by rays (fig. 5). The new cambia arise as separated portions which may start division at different times. Uusually they appear first external to phloem strands, and gradually extend laterally. At the broad rays the

cambium zone often bends inwards and new strands are formed in an oblique position.

In old rapidly growing stems, where a cambium commences the formation of secondary tissues as soon as it is initiated, the completion of the ring is brought about by divisions of cells much external to those forming the first part. This may result in cells of the cortex external to the fibre strands dividing to form a part of a cambium, and the fibres themselves becoming enclosed in secondary tissues (fig. 6).

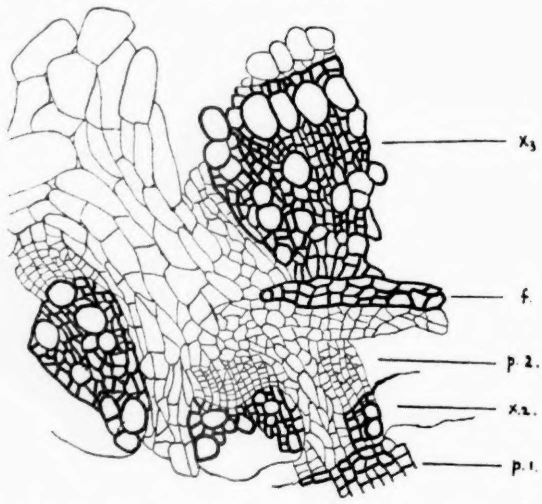

FIG. 6.—*O. ciliatum.* Part of transverse section of stem showing the inclusion of fibre strand by secondary tissues.

p. 1, *p.* 2, phloems of successive zones; *p.* 1 is lignified. *x.* 2, *x.* 3, xylems; the outermost part of *x.* 3 shown is not yet lignified. *f*, fibres of the pericycle. × 100.

In old branching stems, where increase is rapid, a new cambium, when formed, arises some distance outside the previous secondary tissues. In such cases a zone of cambial cells internal to the new xylem is formed, which divides to produce phloem internally and xylem externally. These intermediate cambia form strands with reversed orientation between the main zones. These reversed strands are usually of small size and occur as separate portions immediately internal to larger strands; they never form continuous zones (figs. 5, 7 A, 7 B). The xylem of the reversed strand is usually, but not always, in contact with the xylem of the next outer zone. In some of them phloem alone is formed; the phloem of these reversed strands is not lignified.

The separation of the secondary tissues into strands and the presence of these small reversed strands gives a much less regular appearance than is the case with the previously described species. This irregularity is further increased by simultaneous division of more than one cambium and continued growth of the cambium of a branch or leaf trace at levels where external cambia are active elsewhere.

In *O. ciliatum* the formation of pericyclic cambia is closely associated

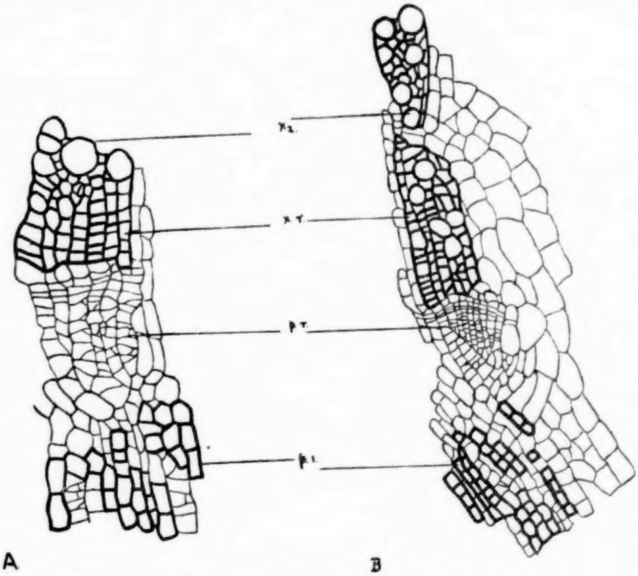

FIG. 7.—*O. ciliatum.* Portions of sections showing reversed strands. In A, a small reversed strand adjacent to the zone outside. In B, a separate reversed strand.

p. 1, phloem of inner zone; *x.* 2, xylem of outer zone; *x.r.*, xylem of reversed strand; *p.r.*, phloem of reversed strand. A, × 280; B, × 185.

with the renewal of activity related to the formation of branches on old parts of the stem. These branches may arise from axillary buds with delayed development or in old stems from adventitious buds formed from the cambium. In the latter case the first initiation is from the most external cambium. When the branch commences growth a new cambium arises which extends downwards and a short distance upwards from its initiation.

Root.—The root system is less extensive than in *O. moniliferum* and quite without the horizontal branches and suckers. The main roots alone have anomalous structure; they are usually 2–4 arch, though the laterals

have 4–5 protoxylems. The first cambium, which persists for about two years, forms new phloem strands between the primary ones. Though the xylem cylinder becomes fluted there is no inclusion of the phloem strands. After the formation of the pericyclic cambium the tissues are laid down in separated strands. There is no trace of the reversed strands in the root. The growth from the pericyclic cambia is often very unequal, increases on two sides being more rapid than elsewhere, and a flattened outline resulting (fig. 8).

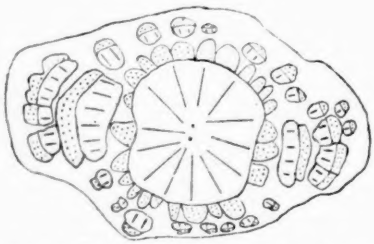

FIG. 8.—*O. ciliatum*. Section of root showing uneven distribution of secondary tissues. ×12.

GENERAL.

The anomalous secondary thickening in these species of *Osteospermum* is of a kind quite different from that described for some other genera of South African Compositae,* in which an external cambium gave rise to tissue containing both xylem and phloem. The formation of successive pericylcic cambia is an anomaly that occurs in various groups of plants,† but does not seem to have been recorded for any of the Compositae.

In the case of the other Composite genera with anomalous secondary thickening, the suggestion was put forward that the condition might be related to the development of a shrubby habit in herbaceous plants that had lost the power of secondary growth. The same argument might be applied to the species of *Osteospermum*, though there are certain difficulties. In the genus the majority of the species are woody, though there are some herbaceous forms. The allied genera, *Tripteris*, *Garuleum*, and *Dimorphotheca*, contain both herbaceous and woody species. In these genera, and in the majority of the species of *Osteospermum*, the woody representatives have normal structure. These genera all belong to the tribe *Calenduleae*,‡ which is a small one with a decided tendency towards the herbaceous life form. The tribe is regarded as a relatively modern one; this herbaceous tendency is one of the signs of its advancement.§ The majority of the

* Adamson, 1934. † Pfeiffer, 1926; Schmid, 1928.
‡ *Cf.* Hoffmann, 1897. § *Cf.* Small, 1919.

genera in the tribe are South African in distribution. Within the tribe *Osteospermum* may be regarded as relatively highly evolved and recent with its specialised fruits and other characters. While the species are most often woody, they are often plants of not large size, and with aerial shoots of limited duration. The development of anomalous secondary thickening might be related to the production of a more persistent shoot system. For example, within the genus *O. moniliferum*, *O. ciliatum*, and *O. coriaceum* belong to one section and are closely allied to one another.* Of these three the last is less woody, and has less persistent shoots than the others and has retained normal structure. *O. ciliatum* stands in an intermediate position in persistence of the shoot system. In this species the formation of the pericyclic cambia, as was pointed out above, is very closely related to the production of branches from the persistent basal parts. Its formation of adventitious branches may also be regarded as an attempt at the formation of a perennial aerial structure. The curious irregularities in the older axis with their reversed strands may be correlated with the production of numerous branches and of successive sets of branches on a limited stem. *O. moniliferum* is larger and more definitely woody than any of the others, and has a completely phanerophytic life form.

It might be suggested that the original plants had normal secondary thickening but shoots of limited duration. The formation of a really perennial shoot had to be met by a new formation of tissues. The argument must not be pushed too far; some of the species with normal growth, *O. spinosum*, for example, can attain a considerable size, and form axes of considerable thickness and undoubted persistence.

On the above hypothesis *O. moniliferum* would be looked upon as the most advanced of the species. The plant has, however, a much wider distribution in South Africa than the others, and from this angle could be regarded as an old one. It is generally a plant of sands, and in the eastern parts of its area is practically confined to coastal sands. Before the question can be regarded as more than a very general hypothesis a large amount of additional information on the other species is needed, both on their structure and distribution.

In the allied genera even the more shrubby species have normal growth. Most of them, however, are plants with not strictly perennial shoot systems. In *Dimorphotheca*, for example, even the most woody species, such as *D. cuneata* and others, have a much less persistent shoot system than *O. moniliferum*. They have normal growth throughout the life of the axes. This retention of normal thickening for a longer period might be regarded as an indication of a less advanced condition, a view put forward on other grounds by Small † previously.

* Harvey, 1865. † Small, 1919, p. 208.

Summary.

1. Anomalous secondary thickening by the formation of successive pericyclic cambia is described in three species of *Osteospermum*. This growth occurs in both stem and root.

2. In *O. moniliferum* the successive zones form continuous concentric rings; in *O. ciliatum* and *O. subulatum* separated strands are formed.

3. In the root of *O. moniliferum* addition of xylem continues beyond the original phloem strands, which become included.

4. In *O. ciliatum* anomalous thickening is confined to the persistent basal parts of the stem. These parts form branches from dormant and adventitious cambial buds.

5. Small strands with reversed orientation occur between successive zones in rapidly growing stems of *O. ciliatum*.

6. Of twelve species examined only three exhibited the anomaly.

7. A possible relation between the anomaly and the development of the phanerophytic habit is suggested.

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SOME STUDIES OF 50-CYCLE WAVE-FORM IN INSULATION TESTING.

By N. H. Roberts.

(Communicated by Professor E. Newbery.)

(With five Text-figures).

(Read August 19, 1936.)

1. Introduction.

Many articles dealing with high-voltage equipment for insulation testing (1) have appeared in the technical Press, and much work has been done on the dielectric strength of insulating materials (2). Information on the breakdown of solid dielectrics is, however, decidedly contradictory, and it is not yet definitely established whether breakdown in such materials is dependent more on the peak than on the virtual voltage applied, or *vice versa*. It is, however, now generally recognised that wave-form is of great importance in insulation testing, even though a knowledge of nothing more than the crest factor is sufficient for many purposes. A sinusoidal voltage wave is desirable. Information is available as to the general effects on testing transformer wave-form of such factors as load capacity and the method of voltage regulation adopted (see, for example, Goodlet's article (3)). It is nevertheless obvious from a study of this paper and the discussion thereon that the merits of a particular equipment cannot be judged without tests on the apparatus itself.

The present paper describes an experimental investigation of the factors which influence the wave-form of the 30-kilovolt testing transformer of the Department of Electrical Engineering at the University of Cape Town. Curves of crest factor for different arrangements and outputs provide a convenient means of representing the results of the tests. The measurements from which the curves were derived were supplemented by oscillographic observations.

2. Equipment and Method of Measurement Used.

The transformer under consideration has a step-up ratio of 1 to 75, and the maximum secondary potential difference of 30,000 volts (virtual) is obtained when the primary is supplied at 400 volts. The primary is fed by means of an induction regulator which allows of a smooth variation of the primary voltage from zero (approximately) to 400 volts, and which itself requires a supply at 200 volts. The transformer possesses a third (tertiary) winding, also known as the voltmeter coil, which gives either 1/500th or 1/1000th part of the high-tension voltage. An R.M.S. voltmeter for the measurement of the virtual voltage, a peak voltmeter and an oscillograph for the tracing of the wave-form may all be connected to this winding.

The crest factors of the voltmeter coil wave-form were determined by dividing the measured peak voltages by the corresponding virtual voltages. For the early readings, an electrodynamometer voltmeter was used for the measurement of the virtual voltage, but trouble was experienced at the lower readings owing to the effect of stray fields, and a valve voltmeter free from this defect was ultimately adopted. The peak voltage determinations introduced more difficulties. Measurement of an oscillogram will yield the peak voltage, once the sensitivity of the recording loop is known, but, as the trace is of finite breadth (of the order of one-fiftieth of the maximum deflection), the accuracy of the value obtained is open to doubt. With a loop oscillograph, moreover, the trace will not necessarily follow rapid variations of wave shape very closely. A valve rectifier circuit was tried (4) but abandoned on account of the imperfections of the rectifiers available. A type of peak voltmeter using triode valves (5) was finally adopted. The estimated accuracy of the indications of this instrument was within 1 per cent.

In all, three methods for the determination of the crest factor were used. In the first two, the virtual value was measured by means of a voltmeter (either an electrodynamometer or a valve voltmeter), while the peak value was measured by means of the above-mentioned peak voltmeter, in the first method, and by measurement of the oscillograph trace, in the second. In the latter case, the direct current required to bring the light spot on to a certain mark on the viewing screen was determined, and the peak of the wave was then brought to this mark by adjustment of a calibrated series resistance. The third method consisted in analysing oscillograms by means of Fourier analysis, and in then computing the crest factor from the magnitudes of the harmonic components. This method was used in a few cases only, on account of the tedious arithmetic. The three methods in general agreed to within 1 per cent.—

a fact which indicates that an oscillogram can be measured up with an accuracy quite sufficient for the purpose.

3. Suspected Causes of Wave-form Distortion.

Possible causes of distortion, most of which are admirably dealt with in reference (3), are outlined below.

(*a*) The secondary voltage of the transformer cannot be expected to be sinoidal if the supply voltage is not. For convenience, the transformer referred to is usually fed from a 10-ampere wall plug which is connected between one line and the neutral of the Corporation three-phase network. The voltage between these points contains an appreciable third harmonic which is practically absent from the voltage between lines.

(*b*) While the induction regulator requires a 200-volt supply, the voltage from line to neutral is about 230 volts and the excess must be absorbed. This is most conveniently done by joining a variable resistance in series with the line, with or without the addition of a variable potential divider. Unfortunately, the current drawn by the equipment and consequently the voltage drop in the series resistance may be decidedly non-sinusoidal. This factor may cause a considerable distortion of the wave at the transformer terminals.

(*c*) The two windings of the induction regulator will, in general, neither carry the same current nor be threaded by the same flux. As a consequence, any harmonics produced in the voltage waves of the two windings will usually differ in magnitude and in phase. When, at low voltage settings, the fundamentals of these voltages are opposed and nearly equal, the harmonics will not cancel out and the resultant voltage wave will be badly distorted. This distortion will vary with the setting, being most pronounced at low settings. Distortion similar to that described in (*b*) above will also occur, owing to the flow of the transformer current through the induction regulator, and as the reactance of the regulator may vary with the setting the deformation due to this cause may also be variable.

(*d*) Even when the transformer is on open-circuit, the self-capacity of the secondary will draw a current which may be large and far from sinoidal. When a specimen is in position, additional currents, also likely to be distorted, may be drawn. These secondary currents may give rise to deforming voltage drops in the transformer and regulators, which drops need not affect both secondary and tertiary windings in the same way. The wave-forms of these windings may differ appreciably under load conditions.

Tests were therefore carried out with the purpose of determining the importance of these several factors. The tests described in section 4 were performed with the secondary on open-circuit.

4. No Load Tests.

(*a*) *i.* The supply was obtained from the wall plug (line to neutral) at 230 volts, the crest factor for the supply itself being about 1·43. A variable resistance of maximum value 180 ohms was connected in series with the line and a potential divider of total resistance about 300 ohms connected across the terminals of the induction regulator.

For each setting, the series resistance and potential divider were

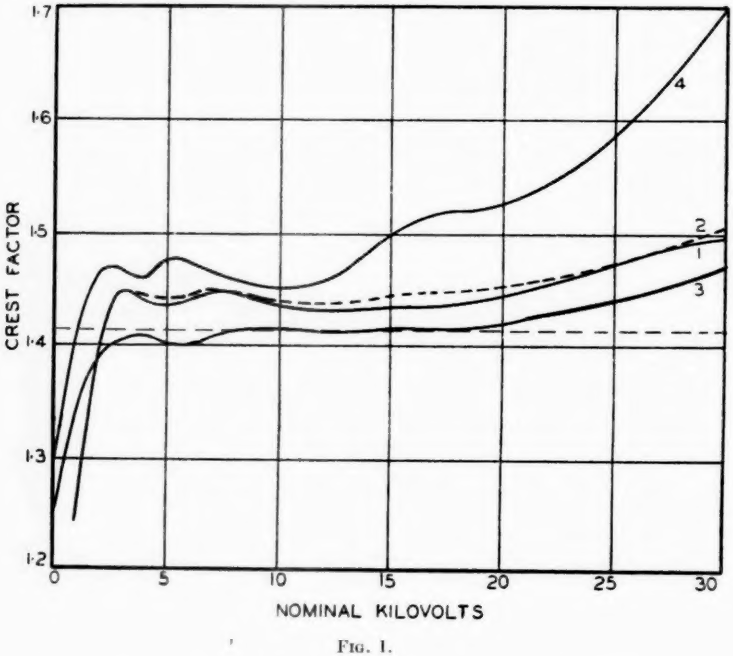

Fig. 1.

adjusted until a voltmeter connected to the voltmeter coil indicated the correct reading corresponding to the graduation of the regulator (*e.g.* 60 volts for 30 kilovolts). The peak values were determined and the crest factors calculated. These values are shown by curve 1 of fig. 1.

(*a*) *ii.* The connections were as above, but the resistances were adjusted once only, to give the correct voltage at 20 kilovolts, and then left unaltered. At other settings the high-tension voltages did not correspond exactly to the indicated values, but below 20 kilovolts the difference was inappreciable. This was due to the fact that the varying transformer

current which tended to cause an additional drop in the resistances was swamped by the practically constant magnetising current of the induction regulator, except at the higher voltages. The crest factors were so nearly identical with those obtained in the first test that a curve has not been plotted. This test was undertaken for the reason that the transformer has in the past always been operated in this manner. Considerable error could arise in operation, however, on account of fluctuations in the supply voltage. The error was eliminated in this test by taking the readings only when the voltage at the induction regulator terminals passed through the correct value of 200 volts.

(*a*) *iii*. This test was similar to the first except that the potential divider was omitted. If anything, the variation of crest factor should have been greater than before for the reason that the varying transformer current would now form a larger fraction of the current in the series resistance. The crest factors have been plotted (curve 2 of fig. 1), and it will be seen that the effect of omitting the divider is small. The reason is as before, viz. that the transformer current was swamped by the induction regulator current which was nearly sinusoidal.

(*a*) *iv*. Similar to test (*a*) *iii*. except that the setting was again made once only, at 20 kilovolts. Again the crest factors were scarcely affected and have not been plotted. Now, however, the high-tension voltage varied considerably from the indicated values, both above and below 20 kilovolts (curve 4 of fig. 4). Compare test (*a*) *ii*.

(*b*) In this test, the supply was taken from two lines of the three-phase network in order to obtain a better supply crest factor. A three-phase transformer was employed to step the line voltage down to 230 volts, and the crest factor of this supply was almost exactly $\sqrt{2}$. The connections were otherwise the same as those used in test (*a*) *i*. The crest factors are shown by curve 3 of fig. 1.

(*c*) The series resistance and potential divider were eliminated in this test, and the supply obtained from a three-phase alternator in the laboratory. The excitation of the alternator was regulated to give exactly 200 volts at the induction regulator at all settings. Unfortunately, the wave-form of the alternator was not good, containing prominent slot ripples, and it was necessary to connect no fewer than three transformers between the alternator and the induction regulator in order to reduce the ripple. One of the supply transformer windings was connected in delta to reduce the distortion caused by the magnetising current of the supply transformers. With the induction regulator and test transformer disconnected, the crest factor of the supply was only very slightly above $\sqrt{2}$ although the wave was not sinoidal. With the testing equipment connected, the crest factors shown by curve 1 of fig. 2 were obtained.

(*d*) The induction regulator was omitted, the variation of voltage being obtained by regulation of the field of the alternator. The intermediate transformers had to be retained. The crest factor of the supply on no load was again nearly $\sqrt{2}$ and the slot ripples were much as before. The peak factors are given by curve 2 of fig. 2.

At this stage it is possible to examine the effects of some of the causes of distortion outlined in section 3.

In both figures a horizontal broken line has been drawn to mark the crest factor 1·414 for sine waves. Curves 1 and 3 of fig. 1 differ only in

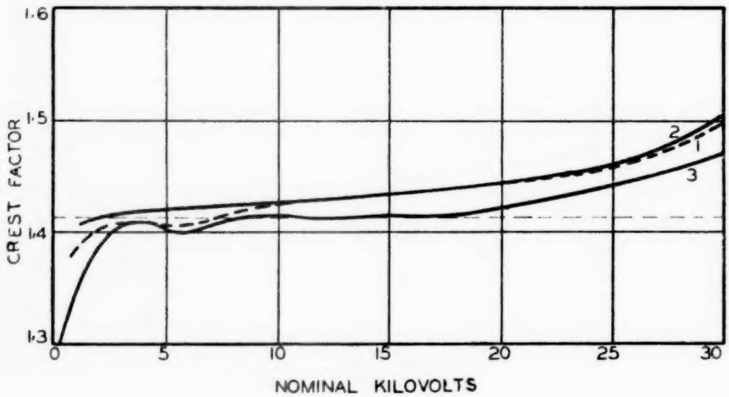

Fig. 2.

that the second is drawn for a case in which the supply voltage had a better inherent crest factor than was the case for the second curve. Curve 3 is closer to the horizontal line, showing that a sinusoidal supply is desirable.

Curve 2 of fig. 1 was drawn for a case in which the potential divider in parallel with the induction regulator was omitted. There is very little difference between curves 1 and 2, which indicates that the potential divider used had little effect on the crest factor. The possibility remains, however, that a divider of lower resistance might improve the crest factor to some extent.

Curve 3 of fig. 2 is curve 3 of fig. 1 repeated. Curve 1 of fig. 2 is similar in shape but on the right rises more than does curve 3. Curve 1 was taken with the resistances cut out, but the reactance of the three transformers, which had to be included in order to reduce the slot ripple, was in circuit, and a reactance is more effective than an equal resistance in increasing the crest factor. Moreover, the supply wave-form was not good. Accordingly, this test cannot be taken as completely conclusive on account of

the lack of a sine-wave alternator. It is very probable, however, that the effect of the resistances used was negligible for voltages below about 20 kilovolts, as the magnetising current of the induction regulator was nearly sinoidal. A calibration takes the effect at any voltage into account. That resistance might have a larger effect was demonstrated by a further test. The induction regulator may also be connected in such a way as to require a supply at 100 volts. It was connected in this way and the

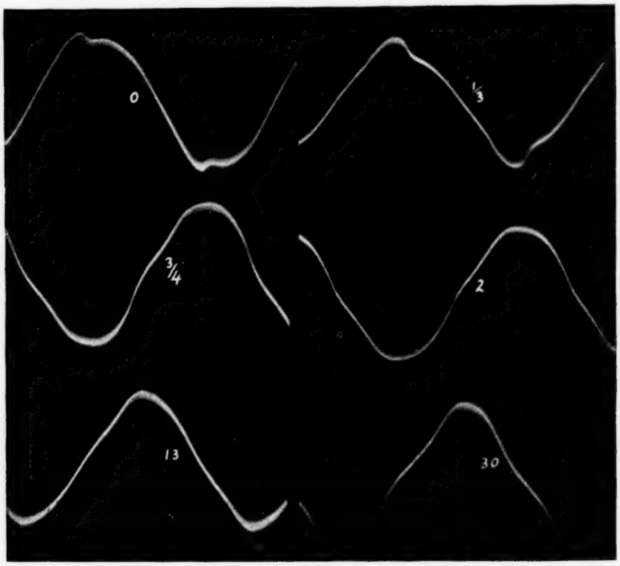

Fig. 3.

230 volt supply dropped to 100 volts by means of a larger resistance. The connections were otherwise identical with those of test (*a*) *i*. The crest factors proved to be very much increased by the inclusion of the larger resistance and are shown by curve 4 of fig. 1.

All the curves, with the exception of curve 2 of fig. 2, were taken with the induction regulator in, and all except this one exhibit irregularities towards the left. The effect of the induction regulator is thus to cause considerable deformation at low settings, but little change above 7 or 8 kilovolts. Photographs of some wave-forms at voltages from 0 to 30 kilovolts with the arrangement of test (*a*) *i*. are shown in fig. 3.

Calibration curves for the equipment are best drawn by plotting equivalent virtual voltages against the setting of the induction regulator

(nominal kilovolts). The equivalent virtual voltage is the virtual voltage of a sine wave, the crest voltage of which is the same as that of the actual wave. In fig. 4 such curves are shown, curves 1 to 4 corresponding to

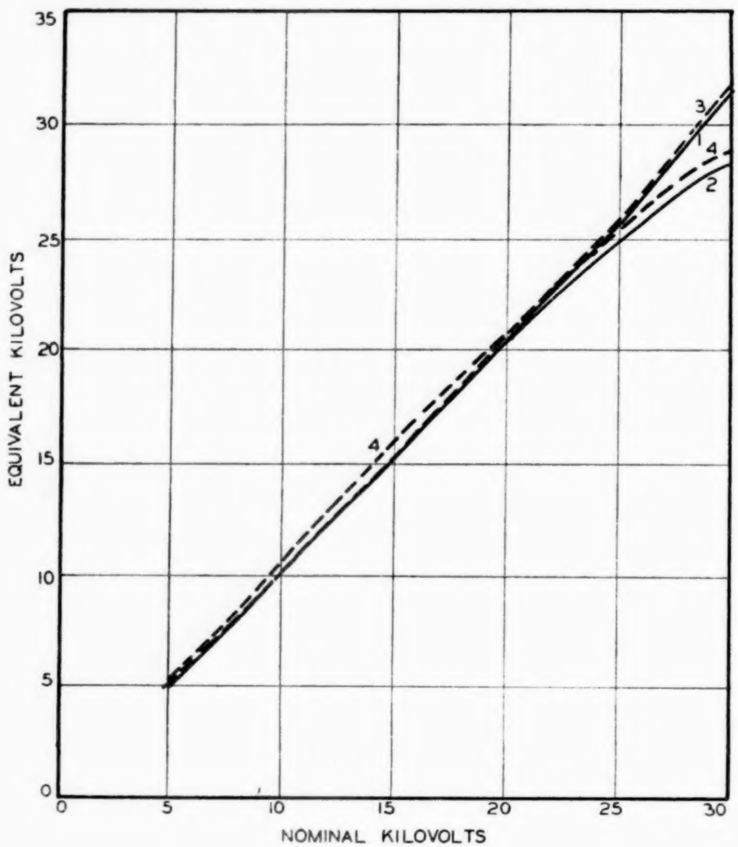

FIG. 4.

tests (*a*) *i.* to (*a*) *iv.* respectively. The effects both of the inclusion of the potential divider and of adjusting the resistance at one setting only are shown up clearly by fig. 4. When, at each setting, the resistance was adjusted to give the correct virtual voltage, the inclusion of the divider had little effect—curves 1 and 3 practically coincide. The drooping of the curves 2 and 4 to the right indicates that the voltages were decidedly

low at the high settings, when the adjustment of the resistances was made once only. With the potential divider included, the voltage was practically correct below 20 kilovolts, but without the potential divider the voltages here were high. The divider therefore improves the regulation somewhat. The arrangements of tests (*a*) *ii.* and (*a*) *iv.* are not to be recommended.

We have considered all the possible distorting factors, with the exception of the secondary current. The next two sections deal with this effect.

5. Secondary Current at No Load.

Even at no load, current will flow in the secondary on account of the self-capacity of the winding (see Reference (3), p. 379). Unfortunately, this self-capacity is very difficult, if not impossible, to estimate with any accuracy. The statement has been made (Reference (3), p. 380) that "The self-capacitance of testing transformers is in general surprisingly high and . . . these high capacitances result in the primary current being leading even on open circuit." Oscillograms of the primary current of the transformer under test showed that this statement does not apply here, as the primary no load current always lagged. A condenser of capacity approximately 0·001 microfarad was then connected across the secondary terminals, when the primary current was found to lead slightly. A partial resonance at the fifth harmonic frequency was noted. A fuller investigation of this point would have required a variable high-voltage condenser, which was not available. While the tests just described were not extensive, yet they showed that the self-capacity of the transformer was probably very much less than 0·001 microfarad. Under transient conditions, the self-capacity might have a greater effect, particularly on account of the fact that it is not concentrated but unevenly distributed along the winding. The next section covers this point.

6. Load Tests.

When a specimen is placed between the testing electrodes and the equipment put into operation, the currents which may flow even before puncture takes place will in general be irregular in form and duration. These currents might cause a distortion similar to that mentioned in section 3 (*b*). Part of this distortion could arise in the impedance of the secondary itself, and this part would affect the secondary but not the voltmeter-coil wave-form. As the currents referred to would be likely to be intermittent, they would almost certainly cause transient surges, which might well produce different effects in the secondary and tertiary windings, on account of the difference between the capacities of these two windings. In other words, it is to be suspected that the wave-forms in

secondary and tertiary windings will not correspond. (See W. E. M. Ayres's contribution to the discussion on Reference (3), p. 400.)

To decide whether this effect was appreciable or not, it was necessary to compare the wave-forms and crest factors of these two windings. A high-resistance potential divider (up to 160 megohms) was placed across the secondary winding and the peak voltmeter and valve voltmeter connected to the divider. This arrangement was found to be unsatisfactory for the following reasons. Firstly, the readings of the peak voltmeter were irregular, apparently for the reason that the input circuit had too high a resistance. Secondly, the peak voltmeter readings correspond to the highest individual peak which occurs after operation has started, while the valve voltmeter reading gives a mean virtual value over a time dependent on the period of the indicating instrument. The readings do not necessarily correspond to each other as the wave-form often changes from cycle to cycle. It was then decided to use two oscillographs, a loop oscillograph on the tertiary winding as before, and a cathode ray oscillograph on the secondary. It soon became obvious, however, that simultaneous photographs or traces were essential, on account of the variation of the wave from cycle to cycle which took place when discharge currents were passing. As a cathode ray oscillograph has only one recording spot, it was necessary to use a switching device by which the two waves could be applied alternately to the same tube. Such a device was developed, in which the two waves were applied to two similar valve amplifiers, which were switched in and out alternately several thousand times per second (6). The trace on the screen takes the form of two dotted lines which may be superimposed and compared.

Several different specimens, including glass, presspahn, mica, micanite, ebonite, celluloid, oil and air, were used in these tests and the wave-forms compared. Usually the comparison was made by eye, the curves being made to coincide, but in certain cases of doubt photographs were taken and the comparison made at leisure. In some cases appreciable differences between the two wave-forms were noticed, but this occurred only when the voltage was well below the breakdown value. Roughness of the electrodes appeared to encourage surges which affected the tertiary wave-form more than the secondary. Somewhat surprisingly, the two wave-forms were always practically identical when breakdown was imminent. Moreover, the wave-form then was the same as that found when the secondary was on open circuit, other conditions being unaltered. The explanation is probably that near—but not at—breakdown, the secondary current is not intermittent and surges are not so likely to occur. If the secondary current is regular, it would seem that the wave-form is not appreciably affected. This can only be true if the current is small, which

cannot be the case if the load has an appreciable capacity. No specimen tested had a capacity greater than about 0·0002 microfarad.

The photographs (fig. 5) were taken during a test on a glass plate, the secondary and tertiary waves being superimposed. The upper trace was taken at 24 kilovolts (breakdown occurred at 25 kilovolts) and the two waves are seen to be practically identical. The lower trace shows irregular differences between the waves and was taken at 7·5 kilovolts.

It may therefore be concluded that the wave-form of the voltmeter-coil may be considered as an accurate copy of the wave-form of the high-

FIG. 5.

tension winding, at least at voltages not far short of the breakdown voltage, provided that the capacity of the load is limited. This conclusion would not be correct if the transformer were used for cable testing purposes when the load capacity is high, nor would it necessarily apply to other equipments.

7. SUMMARY.

The effects which influence the wave-form of a particular testing transformer were investigated experimentally. From the tests the following conclusions were drawn:—

(*a*) A sinusoidal voltage supply is desirable, but is not essential if the deviation from the sine form is only slight.

(*b*) If the regulation of the voltage involves the use of series resistance, operation is satisfactory provided that the resistance has to absorb not more than about 20 per cent. of the supply voltage. A potential divider used in conjunction with the series resistance is convenient for the precise adjustment of voltage, but has no further advantage in particular, unless

the adjustment is made at one point only, when the divider reduces the departure from the nominal voltage.

(*c*) The induction regulator introduces considerable distortion at the lower end of the scale, but as such settings cannot be accurate in any case this effect is of little importance.

(*d*) The voltmeter coil gives a sufficiently accurate copy of the wave-form at the high-tension terminals for most practical purposes.

(*e*) A calibration curve (equivalent virtual voltage *vs.* nominal voltage) for the particular arrangement used is necessary and a voltmeter should be kept connected to the voltmeter coil. The peak voltage should then be known correct to 1 per cent. from 5 kilovolts upwards.

(*f*) A cathode ray oscillograph tracing the high-tension voltage wave will settle any doubts which may arise in cases not covered by the above tests.

(*g*) Each equipment must be judged on its own merits.

8. Continuation of Work.

Similar work on the 150 kilovolt transformers of the Department of Electrical Engineering is projected. As the transformers are not provided with induction regulators, tests previous to 4 (*d*) will not be carried out. A suitable high-resistance potential divider is under consideration.

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A DEVICE FOR THE SUPERPOSITION AND SIMULTANEOUS DELINEATION OF TWO WAVE-FORMS ON A SINGLE CATHODE RAY OSCILLOGRAPH SCREEN.

By N. H. Roberts.

(Communicated by Professor E. Newbery.)

(With three Text-figures.)

(Read August 19, 1936.)

1. Introduction.

Several methods of tracing two independent waves on the screen of a normal cathode ray oscillograph have been published. The waves are applied to the tube alternately. In the majority of these methods (References 1 to 4) the waves are interchanged at intervals of the order of one fiftieth of a second, and only recurrent phenomena may thus be studied. Garceau produces a fine-grained structure on the screen by using a switching frequency of 80,000 cycles (Reference 5), but the traces on the screen are separated, making the comparison of wave-forms difficult.

The device described in this paper employs a high switching frequency and allows the traces on the screen to be superimposed. Transient phenomena may be studied, and slight differences in wave-form readily shown up.

2. Description of Device.

The circuit employed is shown diagrammatically in fig. 1. The mode of operation is as follows:—

The two input voltages are fed through resistances R_3 and $R_3{}^1$ to the grids of the amplifier valves V_3 and V_4, which have a common anode resistance R_1. The grids of V_3 and V_4 are directly connected to the anodes of the switching valves V_1 and V_2 respectively. A valve oscillator of output 50 volts at the switching frequency, feeds the control grids of V_1 and V_2 in push-pull through grid-leaks R_4 and $R_4{}^1$. When V_1 takes no grid current, the full (negative) potential which exists between points A and B is applied to the grid, and the anode current is cut off. When,

however, grid current flows, the voltage drop in R_4 is sufficient to hold the potential of the grid almost constant at about -1 volt relative to the cathode. Anode current commences to flow just before the start of the grid current, and has a square-topped wave-form. The anode current of V_1 when flowing, passes through R_3 and reduces the potential of the

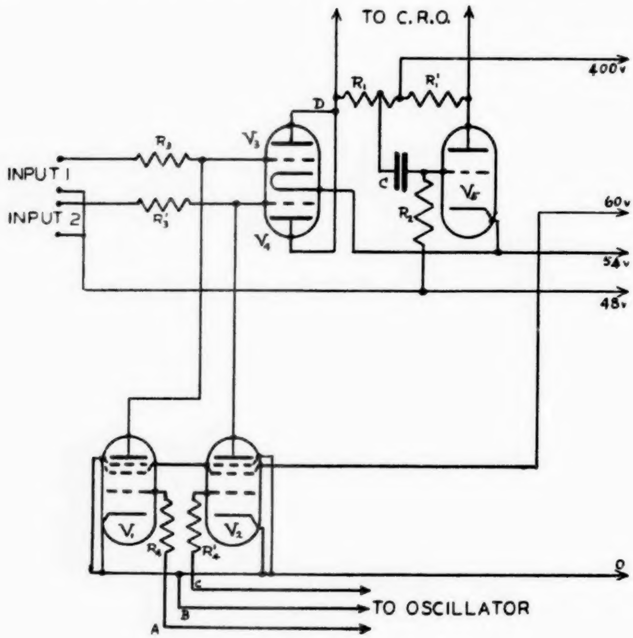

Fig. 1.

grid of V_3 to below the point where the anode current of V_3 is cut off. This state, during which the voltage applied to "input 1" is not effective, continues for half a cycle of the switching frequency. During the next half-cycle, V_4 is ineffective and V_3 comes into operation. The valve V_5 is necessary if balanced deflection is required for a high vacuum cathode ray tube, and is a conventional phase-reversing amplifier fed from a tapping on R_1.

The components used were as follows: V_1 and V_2 Type 57 high-frequency pentodes; V_3 and V_4 one Type 19 Class B valve; V_5 one section of a Type 19; R_1 and R_1^1 200,000 ohms; R_2 1 megohm; R_3 and R_3^1 10,000 ohms; R_4 and R_4^1 1 megohm; C 0·2 microfarad.

The potential of the point D varies in accordance with the alternations of the input voltages 1 and 2 alternately, and the cathode ray spot travels rapidly from one curve to the other, dwelling on each curve for nearly half the periodic time of the switching frequency. Two dotted curves appear on the screen. As fifty to one hundred dots per cycle of the applied wave are necessary if a nearly continuous curve is to be produced, the

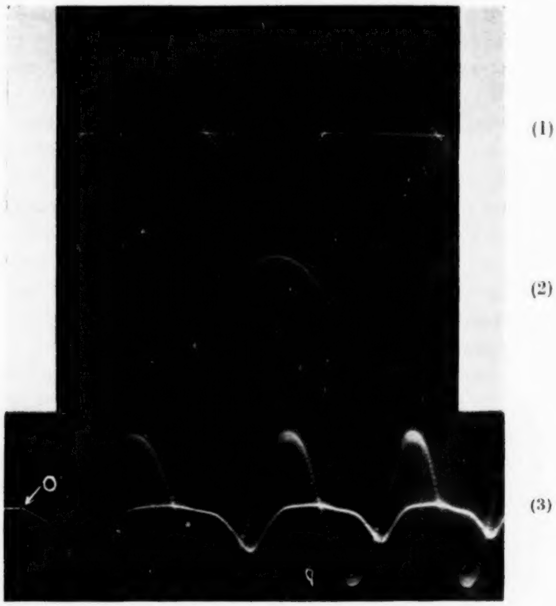

Fig. 2.

switching frequency must be of the order of 10 to 20 kilocycles for an applied wave of frequency up to 400 cycles per second. Although this switching frequency is apparently low for a valve circuit, we are dealing with square-topped waves, and harmonic frequencies up to a megacycle or so must be handled. Stray capacities are thus of importance. The time constant of the circuit composed of R_3 and the anode-earth capacity of V_1 must, for example, be kept small compared with the periodic time of the switching frequency. By decapping the valves and limiting R_3 to 10,000 ohms, a switching frequency of 20 kilocycles was attained. As the impedance of the input voltage source is in series with R_3, this impedance must also be limited (to about 10,000 ohms) and should preferably

be resistive. If these limits be exceeded, modulation of one wave by the other may occur. Such modulation will also occur if the coupling condenser C is too small. As the low-frequency applied voltage is "chopped" at high frequency, it might at first sight appear that the coupling circuit $C-R_2$ need not be effective below the switching frequency. That this is not so, the following argument will demonstrate. Assume that the input terminals 2 are short-circuited and that a sinoidal 50-cycle voltage is applied to input 1. The trace should take the form of a dotted sine wave with a dotted zero line. This fact may also be expressed by the statement that the potential difference across R_1 is a 50-cycle function of time modulated by a rectangular wave of switching frequency. The mathematical expression for this modulated wave contains a term of 50-cycle frequency, corresponding to a low-frequency component of voltage which the coupling circuit must transfer to the grid of V_5 without change of magnitude or phase. If any change of magnitude or phase takes place, then both the sine wave and the zero line are distorted. With the coupling shown, the modulation is less than 1 per cent., which amount may be greatly reduced by feeding a small anti-phase portion of each wave into the input circuit of the other. A direct coupling between D and the grid of V_5 would eliminate this effect.

The photograph (fig. 2) shows (1) a 50-cycle wave with zero line, (2) the same wave applied to both input circuits in order to test the equality of amplification of V_3 and V_4, and (3) the terminal voltage and inrush current of a transformer switched in at O. These exposures, taken with a sliding plate camera, show the dots, which incidentally provide a useful time scale.

3. Other Circuits.

While the above device is the only one which has been used by the author, two other arrangements have been partially developed. As they have been applied to a gas-focussed tube only, the phase-reversing amplifier V_5 has not been used, although it could easily be included.

The circuit used in the first of these arrangements is shown in fig. 3. The connections of V_1 and V_2 are not shown as they are the same as in fig. 1. The resistances r and r^1 are of 100,000 ohms each and W and W^1 are small metal rectifiers (Westector WX6). Without W, the potential of the point E would follow the potential variations of the anode of V_1 exactly. These variations have a wave-form which is not precisely rectangular, there being a slight change in the potential of E during the "in" half-cycle on account of the fact that the control grid potential does not remain exactly constant at -1 volt. For this reason, the dots produced are somewhat ill-defined, especially at high switching frequencies. W,

when included, prevents the potential of E from rising appreciably above 48 volts, but does not restrict its fall. The action of W is to plane off the uneven top of the switching wave, resulting in more sharply defined dots. The disadvantage of this arrangement is that the two input circuits are at different high-frequency potentials and cannot both be earthed.

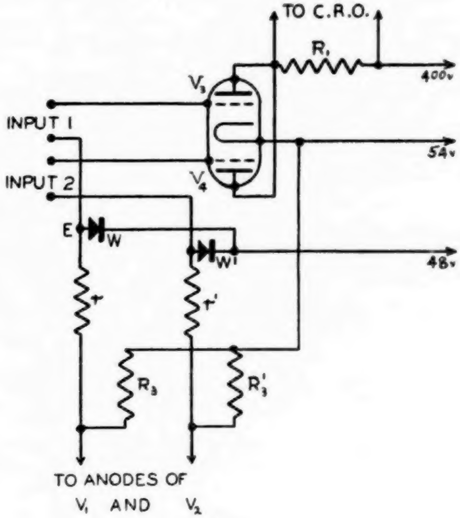

FIG. 3.

In the second arrangement, the only valves used are V_1 and V_2, the control and screen grids of which are connected as before, except that the screen grid potential may be raised to 100 volts or more. The anodes of V_1 and V_2 are connected together and supplied at 400 volts through a resistance of 100,000 ohms, while the input waves are now applied to the suppressor grids, suitable bias being provided. The alternating voltage developed across the 100,000 ohm resistance is applied to the cathode ray tube. Again the departure of the switching wave from the rectangular form prevents the dots from being really sharp, the effect being more noticeable with this circuit. The definition should be improved by replacing the sinusoidal wave applied to the control grids by a rectangular wave. The advantage of this arrangement is that the impedance of the input circuits is not restricted.

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THE EXTERNAL SEXUAL CHARACTERS OF SOUTH AFRICAN HARVEST-SPIDERS.

By R. F. Lawrence, B.A., Ph.D., Director, Natal Museum.

(With Plates XIV and XV.)

(Read September 16, 1936.)

In South African Harvest-spiders, as in those from other parts of the world, external sexual characters occur in all of the three suborders into which the order is divided. In the following paper these characters are described in the suborder Laniatores, members of which compose from 70–80 per cent. of the South African fauna, and the situations of the body in which they occur are compared with those of the remaining two suborders. These external sexual characters are developed in males, and for the most part take the form of processes or outgrowths of chitin, forming strong teeth, spines, or tubercles; they may also appear in the relatively stronger development of structures such as pedipalps and chelicerae, or as differences in the shape and proportion of a given structure. These characters in the Laniatores all have to do with modifications of external form; there are no secondary sexual characters of a glandular nature as in Cyphophthalmi.

Suborder LANIATORES.

In the South African members of this suborder external sexual characters occur on the following structures and segments of the body and its appendages:—

Legs.—The metatarsus of leg II is usually provided with minute teeth in certain species of the genus *Metabiantes*, viz. *M. pusulosus* and *M. leighi* (fig. 1). These teeth though minute are quite distinct on the metatarsi of the males, while those of the females are perfectly smooth. In other species such as *Metabiantes nigrotarsus* the metatarsus is incrassate as well as toothed (fig. 2). In *Metabiantes zuluana* the trochanter of leg II is swollen and considerably larger than those of the remaining legs (fig. 3); in this species the tibia and metatarsus of leg II are also toothed though not incrassate (fig. 4). The external sexual characters in *Metabiantes* are thus all associated with the second leg.

In *Cryptopygoplus rhodesianus* (Fam. Assamiidae) the second leg appears to be considerably shorter in the males than in the females, though this is a point which requires the examination of further material for its confirmation.

CHELICERA. (a) *Basal Segment.*—This segment may be provided dorsally with a large beak-like process as in *Cryptobunus maritimus* (fig. 5), or with a strong tooth on its outer side as in *Cryptobunus silvicolus* (fig. 6), or with a large bifid tooth on its inner side as in *Graemontia natalensis* (fig. 7). The armature of the segment varies a great deal in different genera throughout the family Triaenonychidae, but it is usually provided on its dorsal surface with 1–3 teeth, which are either absent or much smaller in females. These teeth are often more or less vertical in the subfamily Triaenonychinae, but project forward horizontally in various genera of the subfamily Adaeinae, such as *Larifuga* (Ann. S. Afr. Mus., vol. xxix, pt. 2, p. 454, figs. 59, *e*, *g*).

(b) *Second Segment.*—This segment is modified by means of tubercles or teeth situated near the base of the claw in *Roewerania natalensis* (fig. 8) and *Cryptopygoplus rhodesianus* (fig. 9); these structures are absent or greatly reduced in the females.

Both segments of the chelicera are distinctly shorter in the male than in the female of *Austronuncia spinipalpis*.

PEDIPALP.—In the Triaenonychidae secondary sexual characters are more frequently associated with this appendage and more strongly accentuated in it than in any other part of the body. Throughout this family the pedipalp of the male is without exception distinctly longer and more robust than that of the female; the segments of the female are proportionately more thick-set. The length of the pedipalp is greater than the body length in the male with the following exceptions: *Larifugella natalensis*, *Adaeulum godfreyi*, *Adaeulum areolatum*, *Adaeum spatulatum*, and *Larifuga granulosa*. The length of the pedipalp is usually less than the body length in the female; it is, however, equal to or a little more than the body length in females of *Larifuga dentifer*, *Austromontia capensis*, *Ceratomontia reticulata*, *Cryptobunus silvicolus*, *Cryptobunus unidentatus*, *Monomontia rugosa*, and in all species of the genera *Rostromontia* and *Austromontia*. In these exceptions the absolute length of the male pedipalp is, of course, still greater than that of the female. In the genera *Acumontia*, *Austromontia*, and *Roewerania*, the pedipalps of both sexes considerably exceed (those of the male to a greater extent) the length of the body; in these forms, however, this constitutes a character of generic importance.

In almost all species of Triaenonychidae the conspicuous teeth which are found on the ventral surfaces of the trochanter and femur are larger in the male than in the female, in some cases very much larger; one of the

few exceptions is *Larifuga weberi*, where the reverse is the case. These teeth also *appear* larger and more distinct in the male, because the other accessory teeth or granules are either small or absent in these segments, while in the female they are irregular, more numerous, and can be less easily distinguished from the main enlarged spines or teeth; the pedipalps of the females of quite different species thus tend to resemble each other, while those of the males are easily distinguishable.

Large outstanding teeth are often found on various parts of the trochanter; these are, doubtless, of sexual significance, as they do not occur in the females. They are found either on the dorsal surface as in the genera *Cryptobunus* (*C. maritimus*, fig. 10) and *Ceratomontia* (*C. fluvialis*, Ann. S. Afr. Mus., vol. xxix, pt. 2, p. 372, fig. 13, *b*), or on the ventral surface as in *Cryptobunus unidentatus*, or on the inner surface as in *Cryptobunus durbanicus* (fig. 11).

In the males the teeth on the ventral surface of the femur greatly exceed those of the females in size. This is especially true of members of the subfamily Adaeinae (*Adaeulum* and *Larifuga*). In females of the subfamily Triaenonychinae the femur itself is generally more compressed laterally and is usually concave on its inner surface. The femur is characterized by a large tubercle on its inner surface in the male of *Graemontia natalensis* (figs. 12, 13).

The remaining segments of the pedipalp, the patella, tibia, and tarsus, in contrast to the two proximal segments, are armed with teeth which are almost always larger in the females than in the males; these are usually tipped with very stout setae. In certain species of Adaeinae, when these segments are quite unarmed in the male, they may be provided with quite large teeth in the female, as in *Larifuga granulosa* (figs. 14, 15). An exception to this rule occurs in the case of the genus *Adaeum* where the inner side of the patella is armed with a large flattened crescentic tooth in the male (*Adaeum spatulatum*, fig. 16).

The tibia of *Larifugella natalensis* (fig. 17) is distinguished by a pronounced swelling at the base of its under surface in the male, a peculiar sexual character not found in other species of the same genus or in any other South African species of Triaenonychidae.

Body.—There seem to be no fixed sexual differences with regard to body size in the family Triaenonychidae. In some species of genera such as *Adaeulum* and *Larifuga*, the male is slightly larger, in other species the female; in most genera there is but little difference in body size, and when differences do occur they are not striking ones.

(a) *Dorsal Surface.*—In the subfamily Triaenonychinae the ocular tubercle is almost always drawn out into an apical process which is longer in the males than in the females (figs. 18, 19); with regard to the dorsal

granulation, especially of the free tergites, the individual granules tend to be a little larger and coarser in the females than in the males, but the difference is not a marked one. The males of *Cryptobunus maritimus* are exceptional in being armed with a row of very large conspicuous teeth, projecting horizontally backwards from the third free tergite (fig. 20).

In females of the subfamily Adaeinae the ocular tubercle is less high, more blunt, and is usually provided with more irregular granules than in the male; there seem to be no sexual differences in the dorsal granulation.

(b) *Ventral Surface.*—External sexual differences are found on coxae I and II, the genital operculum, and the anal operculum. The males are provided with a large and distinct tubercle on the anterior margin of coxa I in *Graemontia natalensis* (fig. 21) and also in *Roewerania natalensis*. The coxa of the second leg of *Adaeulum coxidens* (fig. 22) is armed near its base with two conspicuous teeth which are totally absent in the female.

A proportionately greater width of the genital operculum in relation to its length has been noted in females of the following species: *Ceratomontia hewitti*, *C. setosa*, *Biacumontia paucidens*, *Montadaeum purcelli*. It is, however, very probable that the relative, if not the absolute width of the operculum in females is always greater than that of males in the family Triaenonychidae; it is the case in *Larifuga granulosa* (fig. 23), and also *L. dentifer*.

The anal operculum is provided with external characters in the males of only one species of South African Laniatores, *Graemontia natalensis*; the structure takes the form of a comb-like row of large granules, which is clearly visible from above (fig. 24).

In the family Assamiidae the four genera occurring in South Africa are too imperfectly known to be able to give a detailed account of their external sexual characters. They do not, however, appear to be developed to anything like the same extent as in the Triaenonychidae. In *Cryptopygoplus* they seem to be associated with the second segment of the chelicera, which is armed with a strong tooth resembling that found in many genera of Triaenonychidae. In the Phalangodidae, represented in South Africa by the single genus *Metabiantes*, external sex characters are all limited to various segments of the second leg; they are not found on other parts of the body.

Suborder CYPHOPHTHALMI.

External sexual characters are present in the same parts of the body in all of the three species of this suborder found in South Africa. They are confined to the fourth tarsus, the genital orifice, and the anal operculum in *Purcellia* and *Speleosiro*.

Suborder PALPATORES.

Three genera of this suborder are found in South Africa, *Cadella*, *Neopilio*, and *Rhampsinitus*. Secondary sexual characters have up to the present not been detected in the two first-named genera, but in *Rhampsinitus*, where they are certainly present, they can be grouped in three categories; by far the most striking of these is the great enlargement of the chelicerae in the males and the stronger and more numerous spines with which they are armed; *Rhampsinitus leighi* is a good example. The femur of leg I is often more incrassate and armed with stronger spines than in the remaining legs. Lastly, there is in some species (*Rhampsinitus leighi*) a very marked difference in the colouring of the sexes, the under surface of the male being uniformly black, while the sternites and genital operculum of the female are white, contrasting strongly with the dark colour of the remainder of the body.

Summary.

In South African Harvest-spiders the number of different forms in which external sexual characters may be manifested is very great. They are far more diverse and numerous in the suborder Laniatores than in the other two suborders occurring in South Africa, the Cyphophthalmi and Palpatores.

Within the limits of the suborder Laniatores they are by far most strongly developed in the large and dominant family, the Triaenonychidae, and more especially so in the subfamily Triaenonychinae, where they occur on nearly all parts of the body and its appendages. In the other two families found in South Africa, the Phalangodidae and Assamiidae, the manifestation of external sexual differences is not nearly so great.

In the Phalangodidae they are found only on various segments of the second leg, in the Assamiidae only in connection with the chelicerae. It must, however, be admitted that the last-named family is less well known than the remaining two.

In the Laniatores structures recognised as external sexual characters have been found in at least fourteen different situations of the body and its appendages; these situations are compared with those of the other two suborders in the following table:—

[Table.

Laniatores.	Cyphophthalmi.	Palpatores.
Body—		
Ocular tubercle.		Colouring of the body.
Third free tergite.		
Coxa of leg I.		
Coxa of leg II.		
Genital operculum.	Genital orifice.	
Anal operculum.	Anal operculum.	
Pedipalp—		
Trochanter.		
Femur.		
Patella.		
Chelicera—		
Basal segment.		Basal segment.
Second segment.		Second segment.
Legs—		
Trochanter of leg II.	Tarsus of leg IV.	Femur of leg I.
Tibia of leg II.		
Metatarsus of leg II.		

EXPLANATION OF PLATES.

Plate XIV.

Fig. 1. *Metabiantes leighi* ♂. Metatarsus of leg II.
Fig. 2. *Metabiantes nigrotarsus* ♂. Metatarsus and tarsus of leg II.
Fig. 3. *Metabiantes zuluana* ♂. Under-surface of anterior half of body.
Fig. 4. *Metabiantes zuluana* ♂. Patella, tibia, and metatarsus of leg II.
Fig. 5. *Cryptobunus maritimus* ♂. Chelicera.
Fig. 6. *Cryptobunus silvicolus* ♂. Segment I of chelicera from above; *t*, tooth on outer surface.
Fig. 7. *Graemontia natalensis* ♂. Chelicera; *t*, tooth on inner surface.
Fig. 8. *Roewerania natalensis* ♂. Chelicera; *t*, tooth on segment II.
Fig. 9. *Cryptopygoplus rhodesianus* ♂. Chelicera; *t*, tooth on segment II.
Fig. 10. *Cryptobunus maritimus* ♂. Trochanter and femur of pedipalp; *t*, tooth.

PLATE XV.

Fig. 11. *Cryptobunus durbanicus* ♂. Trochanter and femur of pedipalp; *t*, tooth on inner surface of trochanter.

Fig. 12. *Graemontia natalensis* ♂. Trochanter and femur of pedipalp; *t*, tooth on inner surface of femur.

Fig. 13. *Graemontia natalensis* ♂. Femur of pedipalp from above.

Fig. 14. *Larifuga granulosa* ♂. Pedipalp from below; patella-tarsus.

Fig. 15. *Larifuga granulosa* ♀. Pedipalp from below; patella-tarsus.

Fig. 16. *Adaeum spatulatum* ♂. Patella of pedipalp; *t*, tooth on inner surface of patella.

Fig. 17. *Larifugella natalensis* ♂. Pedipalp from the side; patella-tarsus.

Fig. 18. *Ceratomontia reticulata* ♂. Ocular tubercle.

Fig. 19. *Ceratomontia reticulata* ♀. Ocular tubercle.

Fig. 20. *Cryptobunus maritimus* ♂. Third free tergite.

Fig. 21. *Graemontia natalensis* ♂. Coxa of leg I; *t*, tubercle.

Fig. 22. *Adaeulum coxidens* ♂. Coxa of leg II; *t t*, teeth.

Fig. 23. *Larifuga granulosa* ♂ and ♀. Genital operculum.

Fig. 24. *Graemontia natalensis* ♂. Anal operculum; *o*, opening between the anal operculum and last sternite.

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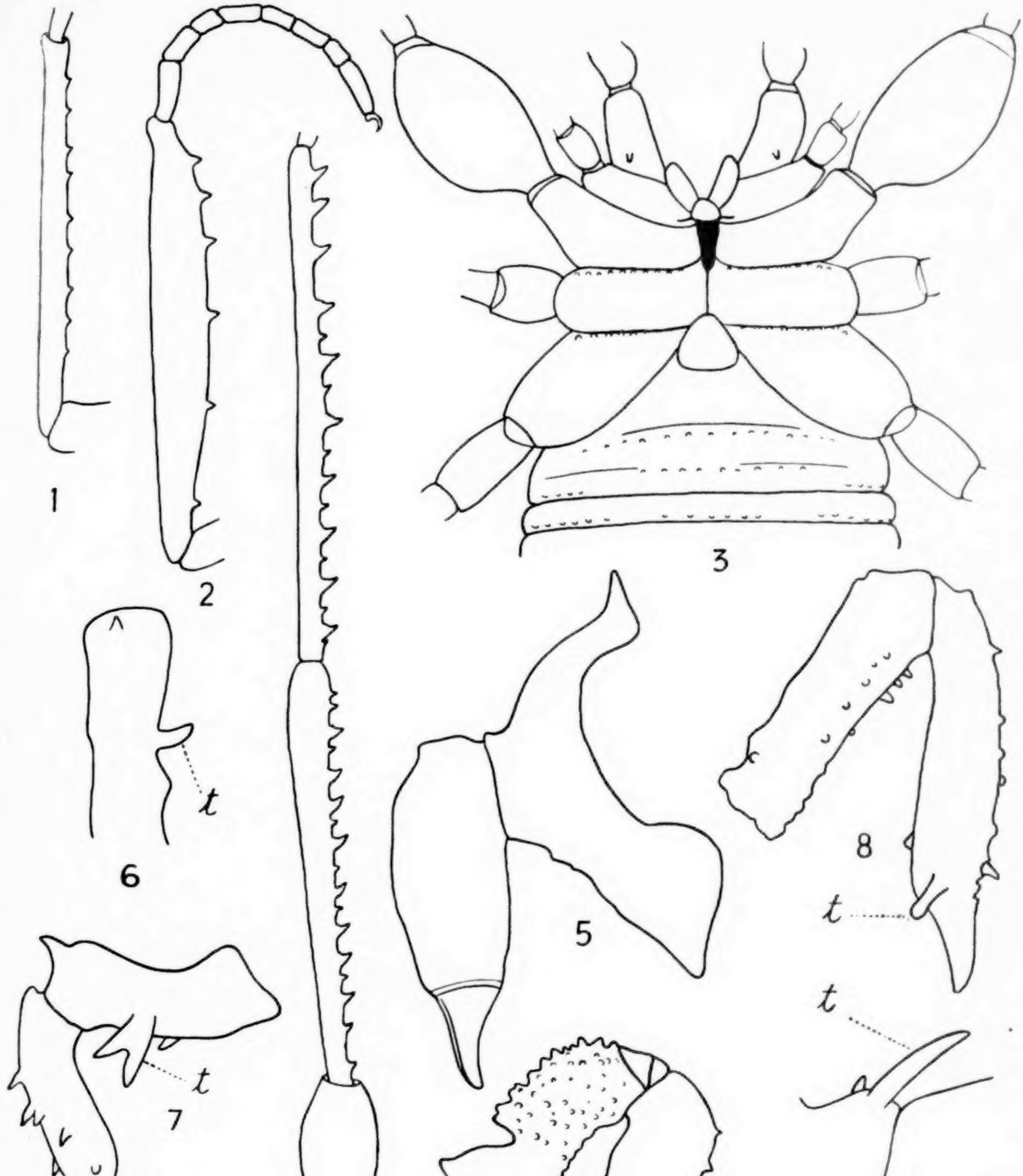

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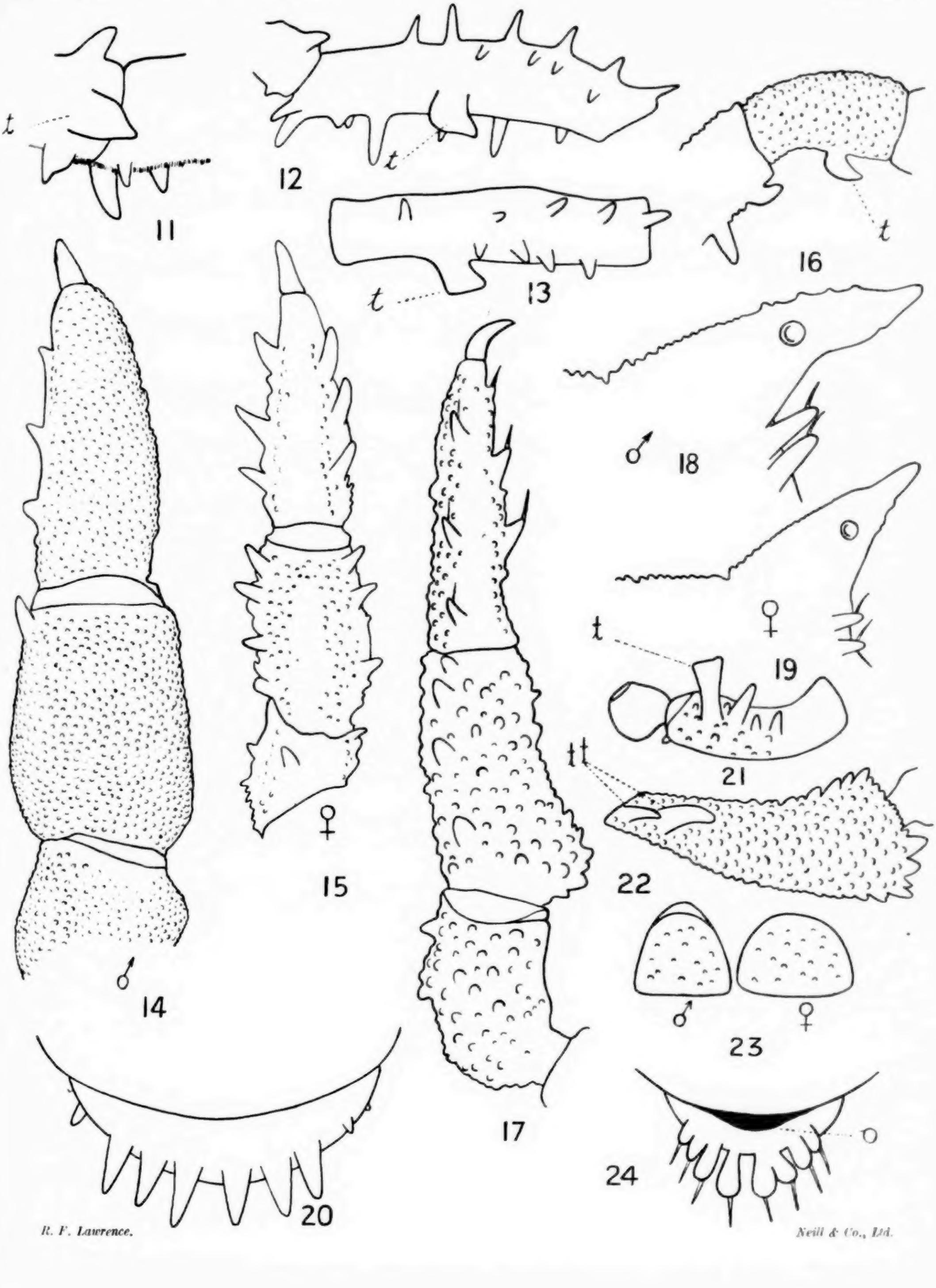

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ROCK ENGRAVINGS NEAR BEAUFORT WEST.

By W. G. Sharples.

(With Plates XVI–XIX.)

(Read August 19, 1936.)

The Nieuwveld Mountains rise abruptly, say, 4 to 5 miles north of Beaufort West. They are broken just north of the village by a deep kloof, above which is the source of the Gamka. At the lower end of this kloof are several terraces or flat-topped hills. On the top of one of these, to the east of the road, at a height of, say, 1000 feet above Beaufort West, there are a number of engravings which, I suggest, fall into three classes.

I. The oldest are drawings of bucks in more or less the style of what Burkitt calls the earliest series, *i.e.* showing an incised outline with fine lines more or less parallel to the outline. On one boulder, along with engravings of two bucks, a human figure is shown in the elongated style typical of many "Bushman paintings" (Pls. XVI and XVII).

II. The engravings in Pl. XVIII seem to be later. Spears and some poor attempts at animal forms are shown. In this case the figures appear to have been rubbed all over inside an outline. In places the rubbed portion can be distinctly felt by the finger to be lower than the surface of the boulder. The rubbing seems to have been done longitudinally. These engravings would seem to correspond with Burkitt's series III, and point to a time when metal spears were in use.

III. Recent drawings, of which Pl. XIX is an example. A horse, a man mounted on a horse, an ostrich, and some rifles are shown. Nearby there is a stone kraal which is said to have been used by the military in the Boer War. That probably dates Pl. XIX.

No implements can be definitely associated with the engravings, though a stone was found which may have been used for rubbing. A few indefinite fragments were found, but the neighbourhood is surprisingly barren compared with the plain just below the mountain, which is very rich in a mixed assemblage of implements and worked stones, among which are some of Smithfield facies.

A suggestion has been made that many of the rock engravings which are found north of Beaufort West may have been done by people who

were on "picket duty," watching for the return of their friends who had been cattle-raiding. It is interesting to note in this connection that many of the engravings referred to in this paper seem to have been executed by people who were facing more or less south-east, *i.e.* in the direction towards where the path from Beaufort and the south comes up the mountain.

There are other engravings besides those figured—some crude, some fragmentary, some indistinct. They are fairly close together and they illustrate the fact that the place where one person has drawn something seems to have an attraction for later "artists." Recent scratchings and a number of carved initials and names serve to show that the rule still holds good.

Beaufort West,
July 1936.

W. G. Sharples. Neill & Co., Ltd.

W. G. Sharples. Neill & Co., Ltd.

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THE SOUTH AFRICAN INTERTIDAL ZONE AND ITS RELATION TO OCEAN CURRENTS.

I.—A Temperate Indian Ocean Shore.

By T. A. Stephenson, D.Sc., Anne Stephenson, and C. A. du Toit, Ph.D.
(Department of Zoology, University of Cape Town).

(With Plates XX–XXIII, and eight Text-figures.)

(Read October 21, 1936.)

CONTENTS.

Introduction.

The Indian Ocean coast of South Africa is influenced by the warm current known as the Moçambique current in the northern, and the Agulhas current in the southern part of its course. The Atlantic coast, on the other hand, is affected by cold water which, in the terminology of the *Discovery* reports, is an upwelling of the body of South Atlantic water known as Antarctic intermediate water; although the water farther offshore is subtropical (Deacon, 1933). The variations and interrelations of the warmer and colder waters are complex, and are as yet incompletely described.*

The prominent Peninsula on which Cape Town is situated lies near the meeting-places of warm and cold water-masses, but these vary in position with season and weather. It is, nevertheless, approximately correct to say that during the summer the northern part of the False Bay †

* See Gilchrist 1902, Deacon 1933, Dietrich 1935, and other sources referred to by these authors.

† The summer temperature of the water in False Bay appears to be dependent partly upon the effect of a persistent south-east wind on the water in a shallow bay.

coast of the Peninsula is chiefly affected by the warmer water, and the northern part of its Atlantic coast by the colder; and the difference between the temperature of the sea at specific localities on opposite sides, on the same day, may exceed 8° C. Possibly there is no small area in the world where water of such different temperature is separated by so little land; and its existence naturally leads to the supposition that the reaction of the intertidal fauna and flora to such unusual circumstances may reveal facts of special interest connected with their ecology and distribution. The position gains attractiveness from the fact that the intertidal fauna of the Peninsula is almost everywhere rich and varied.

It has therefore been the aim of this department, during the past six years, to carry out a general investigation of the situation described; and we wish to acknowledge contributions towards the expenses of this work from the following sources: the Trevelyan Fund of the Royal Society (London); the Carnegie Corporation; the Council of the University of Cape Town; and the South African Research Grant Board. Thirteen persons have so far been engaged in the research. The present paper is intended to be the first of a series which will develop the subject gradually. As the work has progressed, side-lines arising from the main study have also been followed up, and the result of one of these has already been published (Stephenson, Zoond and Eyre, 1934). The investigation is at present limited to the biota of rocky parts of the coast.

In order that the connection between the papers in the series may become apparent as they appear, it is necessary to explain the general plan upon which we are working. The investigation comprises the following parts; and, although it is concentrated more particularly on the Peninsula itself, it extends farther afield wherever circumstances permit.

(I) A general ecological study of the South African intertidal belt at a series of localities extending from Durban on the east coast to Port Nolloth on the west. These two places lie at nearly the same latitude, but, whereas at Durban the influence of the warm current is so strong that reef-corals are present (in spite of the fact that Durban lies far south of the tropic of Capricorn), at Port Nolloth the effect of the cold water is in full force. The eight localities chosen for survey (figs. 1 and 2) are Durban, East London, Port Elizabeth, Still Bay, St. James (in False Bay), Oudekraal (west coast of the Cape Peninsula), Lamberts Bay, and Port Nolloth. Six of these general surveys have already been carried out, that of Still Bay being the first. Still Bay * represents, in the series, a place which

* We are much indebted to Professor C. G. S. de Villiers, of Stellenbosch, for the information that the fauna at Still Bay is a rich one; this decided our choice of the particular spot.

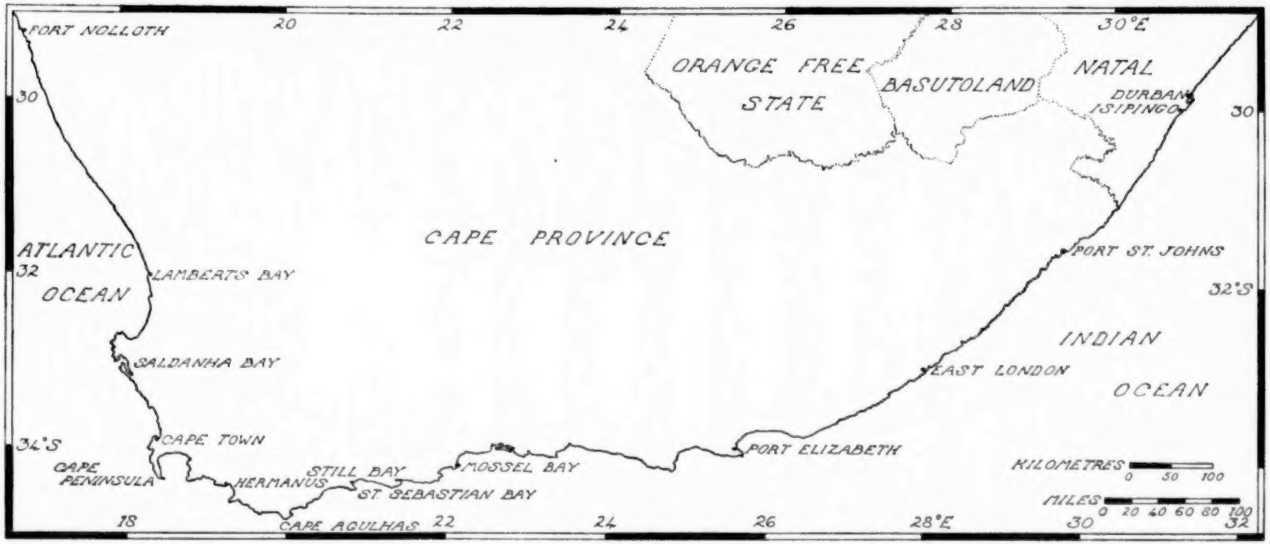

FIG. 1.—A map of South Africa, showing the positions of some of the places mentioned in the text. Others are marked in figs. 2 and 6.

might be expected to be out of reach of the colder waters, on the Indian Ocean side of Cape Agulhas, but by no means as strongly subject to the effect of the warmer water as Durban. Whereas Durban provides a picture of the transition from tropical to temperate conditions, Still Bay appears to provide an example of conditions which, while purely temperate, lie towards the warmer end of the temperate scale.

(II) A second branch of the work consists in choosing, from among the organisms studied in the course of the general survey, a limited number of *unrelated* plant and animal species, which seem from their distribution to be particularly sensitive to the effects of temperature, and in following out the distribution of these forms in more detail. This part of the work has already been started. A variation of the same procedure is the selection of a particular *group* of animals or plants, the study of which seems likely to produce a significant result, and to investigate the distribution and bionomics of these intensively. The first such group to be chosen has been the molluscan family Patellidae, and the study of these forms is well advanced.

(III) It is proposed, as the field-work advances, to conduct experiments on the reactions of specific animals, their eggs and larvae, to temperature variations, with a view to interpreting their observed distribution in terms of their reactions to controlled conditions of temperature in the laboratory. This work can proceed concurrently with other branches; but so far has advanced very little.

(IV) It will be necessary, sooner or later, to summarise from the systematic literature the distribution of at least a selection of the intertidal organisms recorded from the South African coasts. Although a considerable mass of such records exists, they are as a rule accompanied only incidentally, if at all, by ecological notes, except where a study of the natural history of some particular species has been made. So far as we are aware this is the first *general* account of a South African intertidal region.

(V) Apart from the studies already indicated, it will be necessary to give as detailed an account as possible of the actual conditions of temperature involved. Since the information available on this head has just been summarised in connection with a forthcoming publication on the ecology of the South African marine algae, by Dr. W. E. Isaac, it will not be discussed in detail in the present paper, but reserved for a later part of the series. A second paper on this subject is also being prepared by Mr. W. J. Copenhagen, and we wish to thank both Mr. Copenhagen and Dr. Isaac for allowing us free access to the data at their disposal. Meanwhile the opening paragraphs of this introduction will make the general position intelligible, and the details which follow, together with figs. 3, 4, 5, and 8, will serve to amplify those paragraphs.

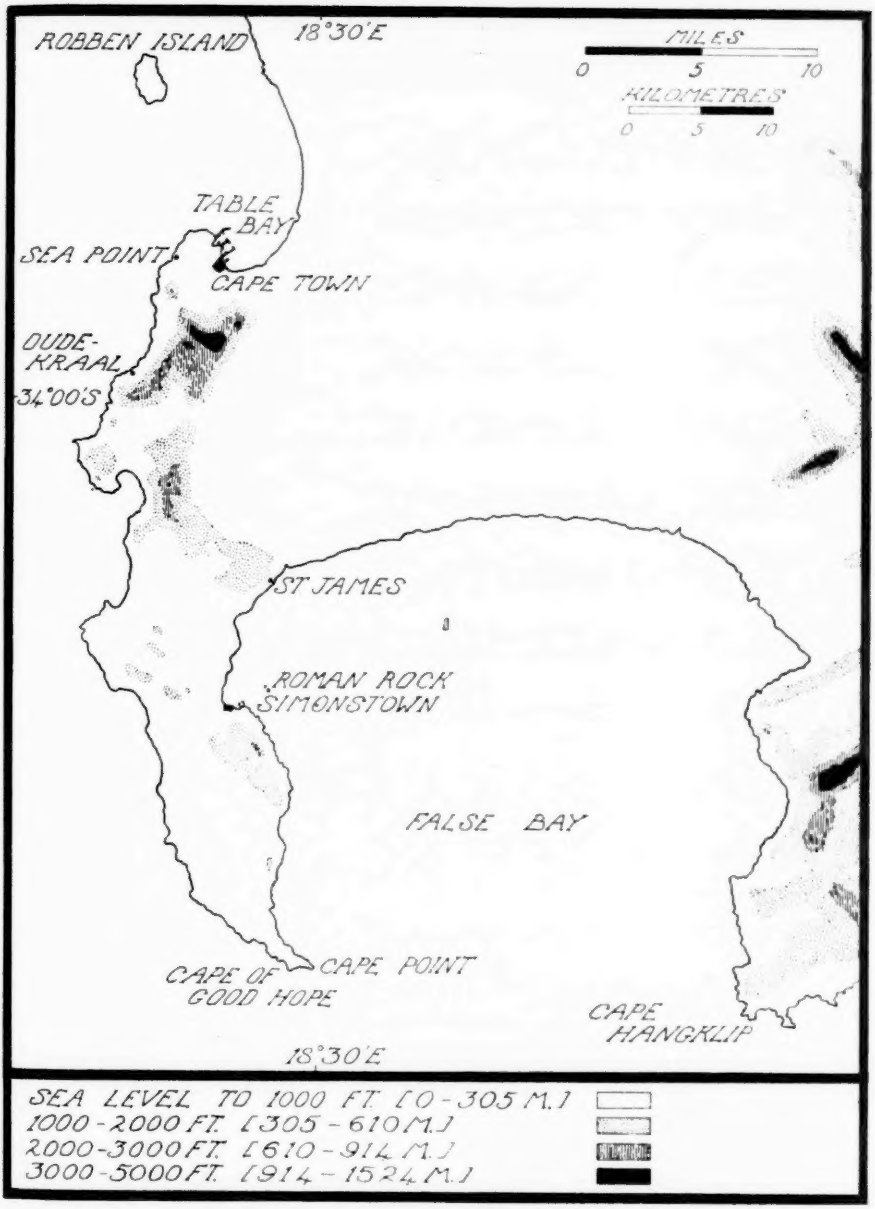

FIG. 2.—The Cape Peninsula. Based on part of the map of the south-western portion of the Cape Province, issued by the Union Director of Irrigation, 1934.

In fig. 3 annual temperature-curves are shown, based on monthly means, for three places on the coast. For the data on which these curves are based we are much indebted to Dr. W. E. Isaac, who has allowed us to use this information from his forthcoming paper. These curves bring out first of all the fact that the temperature at Port St. Johns (south of Durban)

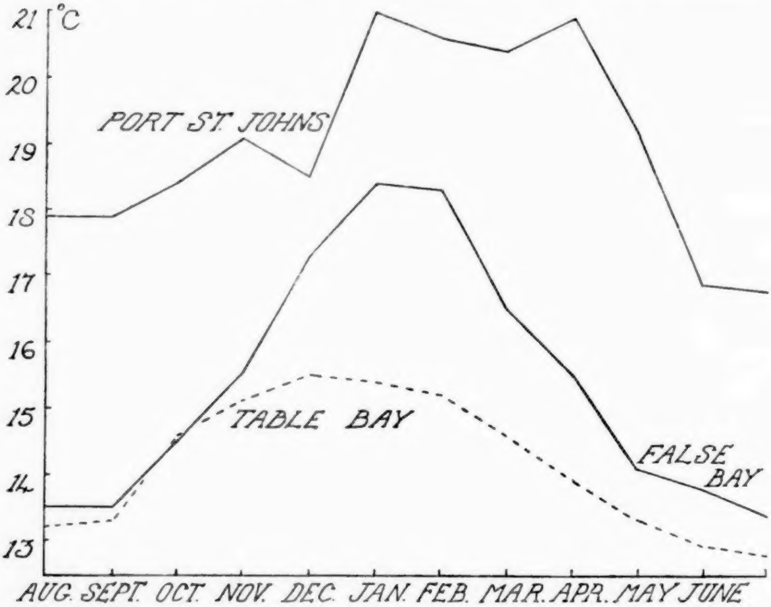

FIG. 3.—Curves showing the annual variation in temperature at three places on the South African coast, based on monthly means. The figure is drawn from data collected by W. E. Isaac, as also is fig. 4. The data extend over the period 1900–1932, and extend for the different localities over 3–6 consecutive years; but there is not necessarily more than one unbroken yearly record per locality.

is altogether higher than in False Bay; and the same of course applies to Durban itself. They show clearly also the contrast between the summer temperature in False Bay and that in Table Bay, at stations only about 26 miles (42 kilometres) apart. In this latter connection it may be noted that the False Bay and Table Bay temperatures given are recorded from offshore stations (Roman Rock and Robben Island), and therefore do not necessarily reflect exactly the inshore temperatures at particular points along the shores of these bays; but they demonstrate the general position. A third point is brought out by fig. 4, in which the curve for False

Bay is compared with that for Walvis Bay. These two curves almost coincide; and this emphasises the remarkable fact that Walvis Bay, a place *in the tropics and far north of the latitude of Durban*, north even of that of Lourenço Marques, has a temperature-range comparable to that of False Bay, and much lower than the range prevailing off Natal, in latitudes far to the south of Walvis Bay.

A few more specific examples may be provided from our own observations. The temperatures given in this paragraph are strictly comparable,

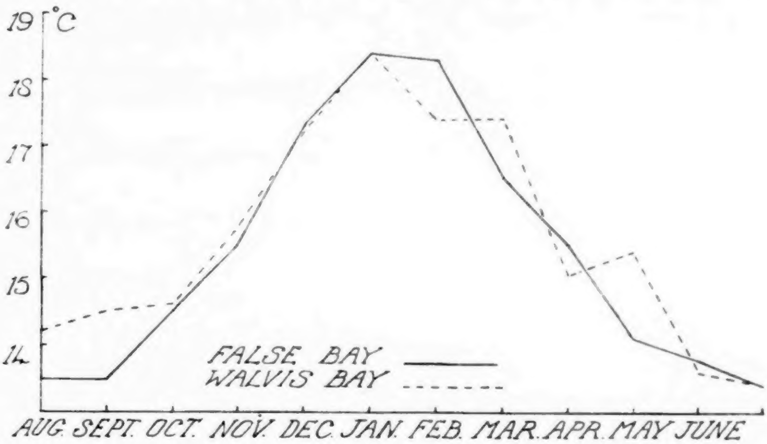

Fig. 4.—A comparison of the curve for False Bay shown in fig. 3 with the corresponding curve for Walvis Bay.

since they were taken with thermometers of known deviation from a standard thermometer, and corrected accordingly. During the fortnight October 22 to November 3, 1935, the temperature of the inshore water was recorded in the early mornings at St. James (False Bay), Sea Point (near Table Bay) and Port Nolloth. The majority of the readings are expressed graphically in fig. 5, and illustrate the contrast between False Bay on the one hand, and Port Nolloth and Sea Point * on the other. The average for St. James for this period was 16·0° C., that for Sea Point 10·0° C., that for Port Nolloth 10·6° C. These readings were taken in spring; probably in the summer a greater contrast could be obtained. We were unable to take the temperature at Durban and Still Bay during the same fortnight; but the average for Isipingo (near Durban), calculated

* We cannot personally guarantee the temperatures given for Sea Point in this figure, as they were taken by a laboratory assistant. We have no reason to suspect them, however, and they are certainly not far from the truth.

from eight morning readings extending from June 27 to July 13 in the same year, was 20·4° C.; and in October would be higher. The only direct comparison we have between False Bay and Still Bay is an average

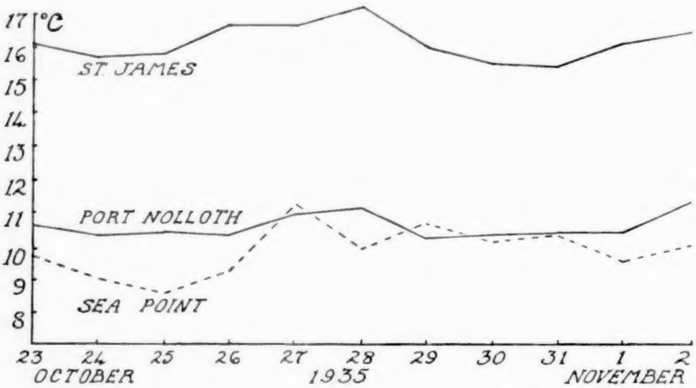

Fig. 5.—Curves showing the inshore temperature of the sea at Port Nolloth, Sea Point and St. James during the period October 23 to November 2, 1935.

of 14·3° C. for Still Bay (morning temperatures for the period September 24–30, 1935), the average for St. James at the same time being 14·1° C. Between these two temperatures there is of course no significant difference, but there is evidence that on the whole the Still Bay area is warmer than False Bay.

Method of Work.

The present work has been carried out as follows. We spent a month at Still Bay in 1932, during which every available tide was used in the observation and description of the seashore and the collection of material. After a preliminary account had been drawn up it was checked and amplified. Since 1932 both we and other members of the departmental staff have carried out further ecological work in other areas; with the result that in September 1935 it was thought advisable to pay a second visit to Still Bay for the purpose of checking particular points in the 1932 notes, in the light of information gained elsewhere. This checking has been carried out by one of us, together with E. J. Eyre and K. M. F. Bright, who will be the authors of later papers in the series, and to whom we are much indebted for their assistance.

The collections made at Still Bay have been identified by the specialists mentioned below, to whom we are extremely grateful for their indispensable

assistance. Some of the material proved to be sufficiently interesting to form the subject of systematic publications. This applies to the sponges (Burton, 1933), turbellaria (Palombi, 1936), polychaets (Monro, 1933), polyzoa (O'Donoghue and de Watteville, 1935) and ascidians (Michaelsen, 1934); and to an insect (Hesse, 1934), a coral (van der Horst, 1933) and a lucernarian (Carlgren, 1933).

Algae. Miss C. I. Dickinson (The Herbarium, Kew); Prof. W. A. Setchell (California); Dr. W. E. Isaac and G. F. Papenfuss, Esq. (Cape Town).

Foraminifera and sponges. M. Burton, Esq. (British Museum).

Coelenterata. A. K. Totton, Esq. (British Museum); Prof. E. Stechow (München); Prof. O. Carlgren (Lund); Prof. C. J. van der Horst (Johannesburg).

Turbellaria. Prof. A. Palombi (Naples).

Nemertinea. Dr. H. A. Baylis (British Museum).

Polychaeta. C. C. A. Monro, Esq. (British Museum).

Crustacea, nudibranchs and fishes. Dr. K. H. Barnard (South African Museum).

Arachnida. Dr. R. F. Lawrence (Natal Museum).

Insecta. Dr. A. J. Hesse (South African Museum).

Mollusca (other than nudibranchs) and brachiopoda. J. R. le B. Tomlin, Esq. (British Museum).

Echinodermata. Dr. Th. Mortensen (Copenhagen); Dr. S. G. Heding (Copenhagen); Dr. K. H. Barnard (South African Museum).

Polyzoa. Dr. C. H. O'Donoghue and Miss D. de Watteville (Edinburgh).

Ascidians. Dr. W. Michaelsen (Hamburg); Dr. A. A. Christie-Linde (Stockholm).

Comment on the Collections Made.

An annotated list is provided on pp. 372–381, which includes all the species collected at Still Bay which have been fully named, as well as references to others which have been determined only as far as the genus. The number of species in this list, however, falls short of the total number actually collected. This is due to the facts that (i) we have not been able to obtain determinations of the lithothamnia and the sipunculids; and (ii) some of the species could be determined only as far as the genus, if at all, either because their identification would have involved an excessive expenditure of time, or because they were indeterminable for some specific reason. In the cases of Didemnid ascidians and algae, for instance, if the material is infertile, identification may be impossible.

Our reasons for publishing this list need a word of explanation. We make no suggestion that it is anything approaching a complete list of the

plants and animals of Still Bay; it is obvious that the number of species which it contains * would be very much increased if collecting were to be carried out more extensively; but when ecological observations are being made, this naturally restricts the time available for collecting pure and simple. We think that none the less the list does represent something of value. Our collecting aimed deliberately at including as many of the commonest species as could be expected under the circumstances,† and the list, therefore, probably does include a high proportion of the ecologically significant macroscopic organisms. It should, therefore, prove valuable for reference and comparison in later papers of this series. In dealing, moreover, with the intertidal fauna and flora of South Africa, one is faced with a problem very different from that of the well-catalogued British coasts. Only a limited number of the intertidal species can be authoritatively named except by European specialists, and the fauna is as yet far from fully catalogued. Some of the first of the common organisms to be noted at Still Bay proved to be undescribed species, and the collections made included at least 23 forms new to science; if the collections were completely worked out, the new forms would probably represent about 10 per cent. of the whole. Under these circumstances we feel that a list of this description has a significance which it might lack in the case of a more fully described area. In order that future workers in this field may be spared some of our initial difficulties, we are gradually forming a collection of named duplicate material from the South African coasts in the zoological department of the University of Cape Town.

Description of the Locality.

Still Bay ‡ (Lat. 34° 23′ S., Long. 21° 25′ E.) is a village near Riversdale, in the Cape Province of South Africa. It lies on the coast of the Indian Ocean some 220 miles (354 kilometres) by road from Cape Town. The village is built beside the mouth of a considerable stream, the Kaffirkuils River. In times of flood the brown water of this river washes down great quantities of debris from the land, and colours the sea outside the estuary. This colour follows the coast to a certain extent, but conditions become

* The list includes 276 names, excluding those of species determined only as far as the genus. So far as we can judge, the unidentified material would bring the total number of species into the neighbourhood of 300.

† The aim here stated should be understood in this instance as having certain definite limitations. For instance, we had not time to catch many fish; and the survey does not aim at covering either the microscopic or sub-microscopic forms, although small species were collected to a certain extent.

‡ This name is printed "Stil" Bay in some Atlases; but as it is a translation of the Dutch "Stilbaai," the correct English form is Still Bay.

purely marine very soon after the estuary is left behind. The slight colour noticeable in times of flood is otherwise absent, and the sea perfectly clear.

Outside the estuary on the western side a rocky tract soon begins (fig. 6). From the point where the coast-line curves away from the estuary the rocks continue for a distance of nearly half a mile (about 760 metres), after which the shore becomes sandy, and then again rocky.

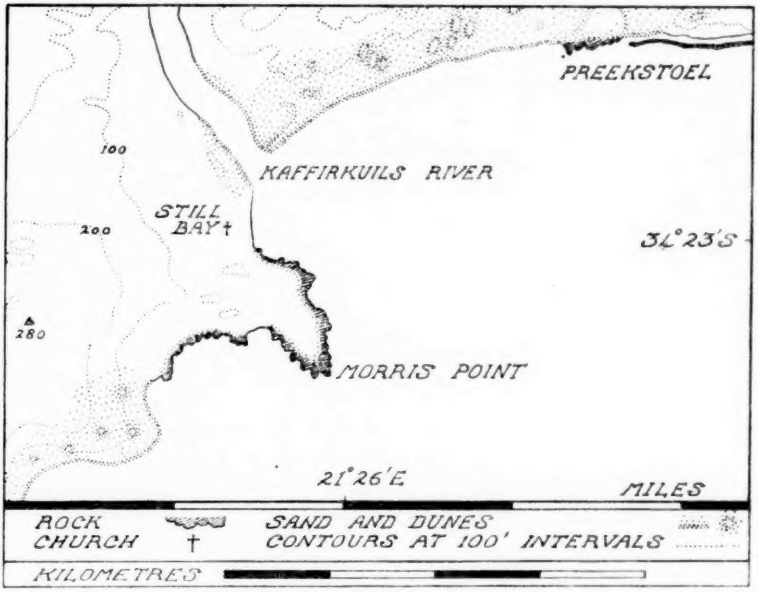

Fig. 6.—The Still Bay district. Based on a portion of the Riversdale sheet of the series of maps issued by the Topographical Survey section of the Union Trigonometrical Survey.

The portion of these rocks well beyond the influence of the river, surrounding the headland known as Morris Point, formed the principal site for our work; but a subsidiary study was made of a second tract of rocks of a very different nature, lying to eastward of the river mouth and separated from it by nearly 2 miles (3·2 kilometres) of sand. This latter locality is known as Preekstoel.

The Rocks near Still Bay.

Along the landward edge of these rocks runs a narrow sandy beach, and the rocky belt itself varies in width from about 60 to over 200 yards (55 to over 180 metres).* It consists of outcrops of hard sandstone with

* The measurements given in this paper were made with a surveying chain.

quartz veins; and among the outcrops are numerous boulders, commonly smooth and more or less rounded. In some places the boulders begin immediately to seaward of the sandy beach, in other places the outcrops run right up to the sand.

Where the boulders are exposed at low water, their population varies according to the level at which they occur. Those on the highest parts of the shore are bare but for the presence of tens of thousands of small periwinkles (*Littorina knysnaënsis*), which are left for hours high and dry in the sun. At somewhat lower levels the boulders become encrusted by small barnacles (*Chthamalus dentatus*) in great quantities, and here other organisms appear. Where, as often happens, the boulders lie in pools, or on parts of the shore which are uncovered at spring tides if at all, they frequently become much encrusted by calcareous and other algae, and the fauna among them becomes more various, being extremely rich on the undersides of many. This gradation in fauna is also evident on the rocky outcrops, and since certain of these are high enough to traverse the whole tidal range, the zonation is sometimes revealed on their sides in a more or less diagrammatic manner. The hardness of the rock is correlated, so far as we have been able to observe, with a complete absence of boring animals.

As the content of the last paragraph suggests, the intertidal belt at Still Bay exhibits the type of zonation usual in such regions. Many of the organisms are subject to definite limits in their vertical distribution, but, since the range of one commonly overlaps that of another, we have subdivided the belt, for purposes of general description, into three easily distinguished regions, which we propose to call respectively the Cochlear zone, the Balanoid zone and the Littorina zone. These terms are intended to apply to those rock surfaces which emerge from the sea at low water, as distinct from pools; since the zonation of the pools forms a modified version of that of the open rock, and will be described separately. The three zones will first be characterised; after which comments on the occurrence of particular organisms will be added. Lastly, reference will be made to a belt lying immediately below the Cochlear zone, and belonging to the sublittoral area; a belt which we call the Sublittoral Fringe.

We cannot state the exact tidal range at Still Bay; but by observing the water-levels on a rock about 13 feet high, near the seaward edge of the intertidal area, we judged it to be less than 8 feet at the strongest tides of January 1932. The Admiralty Chart including Still Bay (No. 2083, Cape Agulhas to Mossel Bay) states "Springs rise 5 feet" for Cape Agulhas, and 6 feet for St. Sebastian Bay and Mossel Bay. Still Bay lies between the two latter localities. Judging from these indications and from information referring to other localities on the South African coast (Bauer, 1933; tide-gauge records for Simonstown; etc.), it will probably not be far

wrong to put the average range of spring tides at Still Bay in the neighbourhood of 6 feet.

I. *The zone of Patella cochlear.* We use this term to denote the lowest zone exposed between tidemarks, at ordinary spring tides. From the seaward fringe of it, and downwards, there would be Laminariaceae on any shore possessing a Laminarian zone; but here these algae are apparently completely absent. The zone remains submerged at neap tides, but becomes uncovered to a greater or lesser extent at springs. It is thus uncovered for a shorter total period in each month than the lower part of the Balanoid zone.

In the absence of Laminarians, we have chosen the limpet *Patella cochlear* (Pl. XXI, fig. 2; and Pl. XXIII) as being characteristic of the zone. This limpet is present in enormous numbers: for instance, on a typical (but not unusually thickly populated) square yard in this region, there were 256 individuals,* some of these being small specimens living upon the backs of larger ones. The rock upon which the limpets are distributed is often much encrusted by thin, greyish-pink lithothamnia †; and the limpets, which are commonly somewhat evenly spaced out on this pinkish ground, give the areas which they inhabit a characteristic aspect. In some places, however, their shells become much infested by epiphytes. The upper limit of the occurrence of *Patella cochlear* is sharply marked; the species is rarely found far beyond the immediate splash of the waves in ordinary weather, or in regions where it is exposed for a very long time in calm weather. The actual level of the upper limit of the zone varies, of course, according to the amount of splashing received locally, or in correlation with other special conditions. For instance, on an outstanding outcrop over which the splash of the surf is unusually high, the actual level is raised. The species often occurs in pools near the sea.

In connection with this zone it may be noted that during the months when the sun is most powerful the intertidal region along part of the South African coast is typically subject to strong wave-action, caused by prevalent south-east winds. During our month at Still Bay (January 1932) the weather was usually windy, with a considerable sea running. Even on hot calm days there was always surf on the rocks, capable of splashing the Cochlear zone except in its least accessible corners. On the

* This square yard accommodated, in addition to the specimens of *P. cochlear*, 41 examples of *Patella longicosta*, 6 of *Oxystele sinensis*, and specimens of *Mytilus perna*, *Chthamalus dentatus*, *Octomeris angulosa* and *Siphonaria*. The area was carpeted with lithothamnia and *Lepadoderma*, with fragmentary tufts of other algae.

† In this paper the term "lithothamnia" is used as a general heading covering genera such as *Lithothamnion* and *Melobesia*; whereas the word "corallines" is reserved for the group of genera including *Corallina*, *Cheilosporum*, *Jania* and *Amphiroa*.

calmest of days parts of the zone would be left to dry in the sun for a time, but this condition is probably not found on a large proportion of days in the warmer parts of the year.

II. *The Balanoid zone.* Above the region of *Patella cochlear* occurs a broad belt in which one of the dominant organisms is a small barnacle, *Chthamalus dentatus*, which is clustered so thickly in places as nearly to conceal the rock. Where the depth of this zone can be measured on a vertical face of rock, it varies from some 4 to 6 feet, according to the degree of splashing received locally. The zone may be differentiated into two sub-regions, an upper and a lower. The lower part, immediately above the Cochlear zone, is rich in species; in the upper part they are fewer. There is no sharp distinction between the two parts, but the lower becomes uncovered at spring and intermediate tides, and not at neaps. At high water of springs the whole Balanoid zone is submerged for some time. Although *Chthamalus dentatus* is so conspicuous in the Balanoid zone, it does extend downwards into the Cochlear zone also.

III. *The Littorina zone.* Above the Balanoid zone the shore is very barren. The most conspicuous inhabitant is the small *Littorina knysnaënsis*, often present in enormous numbers. The rapidly running isopod *Ligia natalensis* is also common under stones, and there are tufts, almost colourless in summer, of the alga *Porphyra capensis*. The moss-like *Bostrychia mixta* also occurs. The rocks of this region are often invaded by Agamid lizards. Many individuals of *Littorina knysnaënsis* are still left uncovered at high water (except perhaps at extreme spring tides) though many others are submerged. Although this snail particularly characterises the part of the shore above the barnacles, it extends down into the Balanoid zone also. In the damper parts of the Littorina zone, and as one approaches the Balanoid, other organisms begin to appear, such as an occasional gastropod (*Helcion pectunculus, Oxystele variegata*, etc.) or crab (*Cyclograpsus punctatus*).

It has not been possible to acquire enough information to enable us to calculate the amount of exposure per month to which the zones just described are subjected; but in order to obtain some idea of their relative degrees of exposure, the movements of the tide were followed for a period of 8–9 hours on each of two days, and the times at which the sea submerged or receded from the various levels were noted. Unfortunately no calm weather was available, and this renders the results very approximate; but the following data are given for what they are worth. They refer to the less rough day of the two, September 25, 1935. The tide on this day was one of moderate amplitude, two days before new moon. At all states of the tide the splash-zone was extensive, reaching well into the Balanoid zone even at low water.

The Cochlear zone uncovered only in part, being much splashed and wave-washed even at low water: the exposure of its highest parts amounted to about 15 per cent. of the tidal period, the latter being calculated as the interval between one high water and the next.

The Balanoid zone was exposed from about 15–64 per cent. of the tidal period, according to level: and a belt of *Mytilus perna*, which occupies much of the lower part of the Balanoid zone, was exposed from about 15–27 per cent. of the time.

The Littorina zone was partly submerged at high water, the remainder being splashed but for isolated patches which still remained dry. The zone was exposed from about 64–100 per cent. of the time, according to level.

The following paragraphs describe further the occurrence on the shore of some of the more important organisms:—

1. *Algae.* The algal flora of the intertidal region at Still Bay is remarkable for the small average size of its members. Species comparable in size to the great *Laminaria pallida* and *Ecklonia buccinalis* of the Cape Peninsula are absent altogether. The largest forms to be found are *Stypopodium lobatum*, *Dictyota naevosa* and species of *Sargassum*, one of which sometimes grows to a length of more than 2 feet. There is thus no Laminarian zone, nor is there any general covering of the rocks by forms similar to the Fucoids of British seas, since the allied Sargassa, although they may occur on open rock, only reach their full size in pools and channels. There are, however, a variety of smaller algae, forming tufts, moss-like cushions, or turf-like areas, as well as others which grow as sheets encrusting the rock. Common species belonging to the category of small plants not encrusting in habit are *Splachnidium rugosum*, *Gelidium pristoides*, *Dictyota liturata*, *Caulacanthus ustulatus*, *Laurencia obtusa*, *L. flexuosa*, *L. virgata*, *Plocamium membranaceum* and the grass-like *Caulerpa ligulata*. All of these are common at low levels (the Cochlear zone or below it), and while some of them (*Laurencia flexuosa* and *L. virgata*, the *Plocamium* and the *Caulerpa*) rarely extend above such levels, the others may occur higher up also, in varying degrees. *Gelidium pristoides* and *Splachnidium rugosum* are characteristic of the Balanoid zone, being particularly in evidence in the lower part of this belt. A handsome red alga of the lowest levels is *Plocamium corallorhiza*. To these species must be added the corallines, which are represented abundantly and in great variety, and which reach their best development below the level of low water, in pools, or in places within reach of the splash of waves. It has not been possible to obtain identifications of all the common corallines, but they include *Cheilosporum cultratum* and *C. flabellatum*, *Jania natalensis* and another *Jania*, *Amphiroa ephedraea*, *Corallina flabellata* and other species of *Corallina*. All of these

are to be found in or below the Cochlear zone, and some of them, together probably with further species, occur at higher levels; but on the whole the corallines of the higher levels, though abundant, are of short growth and often silted up or overgrown by epiphytes. Turning to purely encrusting forms, the lithothamnia are represented by several species with a distribution similar to that of the corallines; and among the non-calcareous forms, the brown expansions of *Lepadoderma africanum* and *Hildenbrandtia pachythallos* are conspicuous. Microphytic algae and epiphytes are also much in evidence, sometimes making so heavy an overgrowth that everything looks dingy. Green algae are on the whole not conspicuous, but *Enteromorpha*, *Ulva Lactuca* and *Codium Stephensiae* are to be found, sometimes plentifully, in habitats suited to them. Lastly, it is noteworthy that wherever limpets occur on the lower parts of the shore their shells are liable to be overgrown by algae, which often make very large tufts, completely hiding the limpet and rendering the appearance of the locality very curious. Corallines and lithothamnia, as well as soft algae, have this habit.

2. *Barnacles*. In addition to the ubiquitous *Chthamalus dentatus*, two larger species are plentiful. One of these (*Octomeris angulosa*) occurs locally in considerable quantity, in seaward positions where it is much splashed, or not exposed for too extensive periods. The other (*Tetraclita serrata*) occurs freely amongst *Chthamalus*, but whereas the latter may be found thickly on the most exposed seaward faces of rocks, as well as on their more sheltered parts, *Tetraclita* occurs most plentifully on rocky faces or ledges turned away from the waves, on the sides of gulleys, or in any position where wave-action is slightly modified. It is not necessarily absent from wave-swept surfaces, but tends to avoid them. This arrangement is most strikingly apparent where rocky ledges slope gradually towards the sea and dip steeply towards the land (Pl. XXII).

3. *Limpets*.* At least seven species of *Patella*, two of *Siphonaria*, and two of *Helcion* are of common occurrence at Still Bay, and they form one of the most important and interesting sections of the fauna. The Patellids exhibit decided zonation. Starting highest up the shore, often among barnacles, is found the small *Patella granularis*; somewhat lower down in the Balanoid zone the larger *P. oculus* † appears, and in the lower and damper parts of the same zone another large species, *P. longicosta*. After this the zone of *Patella cochlear* begins, and in the same zone are to be found *P. argenvillei*, *P. barbara*, and *P. miniata*, which also extend more or

* The word "limpet" is used here to denote any *Patella*-like gastropod, irrespective of its systematic position.

† *P. oculus* is very frequently attended by commensal turbellaria (*Notoplana ovalis*), which crawl about the mantle. There are often several worms to one limpet. We have seen these flatworms in *P. longicosta* also, but much more rarely.

less into the lower Balanoid zone, especially on vertical or overhanging surfaces; and *P. miniata* frequently occurs under stones. In this paragraph only the order in which these species appear from above downwards has been noted: actually their zones overlap considerably. For instance, *P. longicosta* is common in the Cochlear zone as well as in the lower part of the Balanoid, whereas *P. oculus* extends higher up in the Balanoid zone than *P. longicosta*, but becomes less common in the Cochlear zone. Of the other forms, *Helcion pectunculus* prefers sheltered and shaded positions; and *H. pruinosa* is found more particularly in pools and damp places. *Siphonaria capensis* and *S. deflexa* are both very abundant in the Balanoid zone, but *S. capensis* appears to be the commoner in the Cochlear zone. The distribution, habits, and food of these limpets are being studied in some detail, and we hope to publish further accounts in future papers of this series. A preliminary note has already appeared (Stephenson, 1936).

4. *Mussels.* The species *Mytilus perna* is common, and forms thick clusters or large densely populated sheets, in many places. These aggregations occur in the lower part of the Balanoid zone, and although they overlap into both higher and lower zones to a certain extent, the lower Balanoid zone appears to be their optimum level.

5. *Tubicolous polychaets.* The worm *Pomatoleios crosslandi* constructs calcareous tubes, which are cemented together to form crusts or masses, often of very considerable size. Although this animal often occurs in pools, and extends into the Cochlear zone, it is, nevertheless, one of the most conspicuous elements in the fauna of the lower Balanoid zone. Another notable tube-builder, common both under stones and elsewhere, is *Gunnarea capensis*, a counterpart of the *Sabellaria alveolata* of British shores.

6. *Spiders and flies.* The intertidal region is inhabited by a common maritime spider (*Desis tubicola*), and by at least one species of small fly (*Telmatogeton minor*), which is extremely abundant. At Preekstoel some nests of the spiders were found, high up on an eroded rock, above the barnacles, among *Littorina knysnaënsis*. Each consisted of a chamber with a neat narrow entry, was made of tough white material, and contained one spider.

7. *Some common invertebrates and fishes.* The most conspicuous common snail-shaped gastropods of the shore, apart from *Littorina knysnaënsis*, are the large *Turbo sarmaticus* (a smaller species, *T. cidaris*, is also frequent), the periwinkles *Oxystele variegata, sinensis* and *tigrina*, and the whelks *Cominella cincta* and *Thais dubia*. These species exhibit a decided zonation, though it has not yet been possible to work this out in detail.* *L. knysnaënsis* extends higher up the shore than any other:

* The zonation of these species, at St. James in the Cape Peninsula, is now being studied.

Oxystele variegata and *O. tigrina* are forms particularly plentiful in the upper parts of the Balanoid zone; *O. sinensis* is abundant in the Cochlear zone and the lowest parts of the Balanoid; *Thais dubia* is particularly numerous in the crevices of the Mytilus zone; and *Cominella cincta* is widespread at all but the highest levels. *Acanthochiton turtoni* is also extremely plentiful. Common crabs are a large rapidly running form, *Plagusia chabrus* (inhabiting chiefly the lower levels), and a small crab, *Cyclograpsus punctatus*. The fishes of the rock-pools present considerable variety, and we had not time to capture a representative series of them; but among the species taken *Gobius nudiceps* and *Clinus superciliosus* may be mentioned as particularly common. Among the echinoderms, the urchin *Parechinus angulosus* is notably abundant in pools, under stones and in other situations, on the lower parts of the shore, and is present in a variety of bright colours. The commonest asteroid is the small, variously coloured *Asterina exigua*, also present in great abundance. Sea anemones of several species are common, and somewhat resemble the forms of many British shores. There is an *Actinia* very similar to the British *A. equina*; a red *Anemonia*-like form (*Pseudactinia flagellifera*); and at least two species which resemble more or less the British *Tealia* (*Bunodactis reynaudi* and *Anthopleura michaelseni*). A species of *Anthothoe*, similar to the British *Actinothoe sphyrodeta*, is very abundant locally.

8. *The fauna of the lower parts of the shore.* As on any shore with a varied fauna, the full richness and variety is only to be seen in suitable parts of the lower levels—in and below the Cochlear zone and to a lesser degree in the lower part of the Balanoid zone; and particularly under stones, in small caves, in pools, and on overhanging surfaces. Some idea of the range of species present may be gained from the accounts given below of the inhabitants of rock-pools, and of the cryptofauna of Preekstoel, which has much in common with that of Still Bay.

9. *The rock pools.* Pools of several varieties are plentiful on the rocks. Some of them are completely isolated and stagnant at low water, others maintain constant communication with the open sea. Among both kinds there are pools large and deep enough for swimming. The pools highest up the shore are of comparatively little interest; but those of low and intermediate level are interesting and well populated, especially when they contain movable boulders, beneath which a great variety of animals may occur. The two descriptions which follow refer to typical pools situated at different levels.

Pool No. 1. This pool lies on the lowest part of the shore, so that the level of its surface is approximately that of the sea at low water of an ordinary spring tide: it is connected with the open sea even at low water. The pool is carpeted with boulders, on the tops of which are specimens of

Patella oculus and *P. longicosta*, of *Siphonaria*, and of the periwinkle *Oxystele sinensis*; together with crusts of *Lepadoderma* and lithothamnia. Beneath the boulders, to whose undersides the water has free access, is a rich variety of species, of which the following list, though by no means complete, gives a fair idea. Encrusting sponges of several colours are conspicuous, including large sheets of a common leathery-grey species (*Chondrosia reniformis*), and good examples of another frequent form, commonly lilac in colour (*Haliclona stilensis*). There are also specimens of *Helcion pruinosa*; richly coloured lithothamnia; a very common periwinkle (*Oxystele sinensis*) and other gastropods; the urchin *Parechinus angulosus*; black holothurians (*Cucumaria sykion*) and grey ones (*Colochirus doliolum*); various compound ascidians; at least three species of nudibranchs; tube-building polychaets (*Gunnarea capensis* and *Nicolea macrobranchia*); the red alga *Laurencia obtusa*; a small gorgonian (*Eunicella papillosa*); the small asteroid *Asterina exigua*; crabs; *Haliotis sanguinea*; and a small very common crimson foraminiferan, *Polytrema miniacium*.

*Pool No. 2.** This pool lies on a high rocky outcrop, and is about 65 feet (20 metres) long, 39 feet (12 metres) wide, and up to about 4 feet (1·2 metres) deep. It is completely isolated from the sea at low water, and lies well below the upper limit of the Balanoid zone. The level of its surface is approximately 3 feet (0·9 m.) above the level of low water at an ordinary spring tide, and consequently about the same distance above the surface of Pool No. 1. It contains an extensive growth of lithothamnia (at a level well above their upper limit on open rock), and also corallines. The most conspicuous alga is a very plentiful light yellowish brown species of *Sargassum*, which makes a prominent growth in many pools of this type. Sometimes it occurs as a long trailing form, attaining lengths of 2 feet or more; sometimes in a much more stunted and shrubby condition. Among it is interspersed a smaller, darker brown species of *Sargassum*, also common. Other algae of the pool are the small *Dictyota liturata* and the encrusting brown *Lepadoderma africanum*. The exposed fauna of the pool (excluding, that is to say, the cryptofauna) includes *Patella longicosta*, *P. oculus* and *Helcion pruinosa*; *Siphonaria capensis*; *Oxystele tigrina*; *Parechinus angulosus*; *Asterina exigua*; *Pomatoleios crosslandi*; *Acanthochiton turtoni*; and a speckled flatworm, *Planocera gilchristi*; a series of forms very characteristic of pools at such levels.

10. *The sublittoral zone.* The region lying immediately below the Cochlear zone may be regarded as the uppermost part of the sublittoral belt. It is as a rule invisible, even at low water of ordinary spring tides,

* This description applies to the population of the pool during our first visit in 1932. At the second visit, in 1935, the pool had lost much of its algal growth, apart from lithothamnia and short corallines.

apart from such glimpses as may be caught of it as the waves withdraw. It is, however, occasionally exposed to a considerable extent, when maximal spring tides coincide with calm weather. This region we propose to call the *Sublittoral Fringe*. At St. James, in False Bay, a typical region on the warmer side of the Cape Peninsula, the zone in question, where most densely populated, presents a remarkable sight (Pl. XXI, fig. 1). It is dominated by a very large species of simple ascidian (*Pyura stolonifera*), locally known as "Redbait," and the great bottle-shaped leathery tests of this animal are so closely packed as to conceal the rock, and present a bristling array of continually spouting siphons. Although we cannot as yet describe its distribution at all fully, we have reason to believe that an ascidian community of this description is widespread in South Africa in a more or less typical form. At Still Bay the Pyurid mentioned does occur in the uppermost sublittoral zone, and is common, but so far as we have seen it does not present the mass-formation described for St. James. It does, however, attain the dense formation on at least some of the rocks at Preekstoel (see p. 363).

The Rocks at Preekstoel.

The biota of the Still Bay rocks offers a close parallel, as will be shown in a later paper, to that of the rocks of parts of the False Bay coast of the Cape Peninsula. At Preekstoel a variation from this general type is to be found in correlation with a different rock-formation.

The Preekstoel rocks begin nearly 2 miles (3·2 kilometres) to eastward of the mouth of the Kaffirkuils River, and continue for some distance. The present account refers to a considerable area of these rocks near the Still Bay end, but not to the whole of their extent, which is too large to be adequately examined in a short time. The tract studied is curious. It consists for the most part of low rocks situated at such a level that they are submerged before the sea has risen half-way at a spring tide; on a day when a measurement was made, they had become submerged approximately $2\frac{3}{4}$ hours after low water, but for the highest spots, which had then become islands. The tract consists of large flat outcrops of a soft, partly calcareous, consolidated dune sandstone, with sandy pools between them, which often contain loose boulders of various shapes and sizes, commonly flat. On and between the outcrops there are in some places very deep pools and crevices; in fact, the seaward part of the tract often consists of a network of rocks with deep winding pools and caverns, in which a great variety of fish is to be seen, many of them brightly coloured.

These details apply to the main part of the tract examined. At the Still Bay end of the area, however, are several large, more or less isolated outcrops, a little higher than most of the others; and from the landward

edge of the principal tract a sandy beach slopes upward to cliffs of sand with rocky outcrops. On the sandy beach are further outcrops, higher in level than those of the principal tract, but still belonging to the intertidal belt.

1. *Boring organisms.* Whereas the sandstone at Still Bay is very hard, that at Preekstoel is of a completely different character, and is so soft that it can often be rubbed down by a finger-nail. It frequently presents a much pitted and eroded appearance, and is honeycombed by holes and burrows, suggesting the activity of boring organisms. If, however, pieces of rock are broken up and the animals extracted, the result is not easily interpreted. Species obtained in this way include the mussel *Barbatia obliquata* and other small bivalves; *Acanthochiton turtoni*; the tube-making polychaetes *Gunnarea capensis*, *Pomatoleios crosslandi* and *Nicolea macrobranchia*; nereids, isopods, small crabs, flatworms, compound ascidians and sipunculids. Most of these forms have not the appearance of true borers, and are also common outside the rock, whether under stones or above them: the sipunculids possibly being true borers. On the other hand, some of the mussels are enclosed in cavities which they may have enlarged as they grew. It must also be noted that the rock is markedly pitted high up the shore, well above high-water level, where, at least at the present level of the strata, there are no boring forms. Without a detailed investigation no definite conclusion can be reached; so far as we can judge, the condition of the intertidal rocks may be partly due to erosion and partly to borers; but a considerable part of its internal population consists simply of crevice-haunting forms.

2. *The rocky outcrops on the beach.* On the lower parts of these rocks a population typical of the upper Balanoid zone is found. There are the common barnacle *Chthamalus dentatus*; the high-level limpets *Patella granularis* and *P. oculus*; and many siphonariae, both *S. capensis* and *S. deflexa*. The algae include *Enteromorpha*; the blackish beard-like *Lyngbya semiplena*; the mossy-brown *Caulacanthus ustulatus*; and *Splachnidium rugosum*. Above the *Enteromorpha* region is the zone in which there is little beyond *Littorina knysnaënsis* in myriads, and Agamid lizards.

3. *The principal tract of rocks.* These rocks, as has already been mentioned, lie in the main at an unusually low level. Their general appearance is peculiarly dingy and unattractive, because of an almost universal coating of short mossy algae of drab coloration, much matted with sand. The actual composition of this coating varies from place to place, but it frequently consists of a short moss-like coralline, overgrown with microphytes and matted with sand. On the highest places this coating tends to be less developed or absent, but is often replaced by fields of more tuft-forming species, particularly *Gelidium pristoides*; and by the moss-like *Caulacanthus ustulatus*.

There are, however, larger algae, found on the lowest part of the shore and in the deeper pools, which present a more attractive appearance. Among the largest are two strap-like brown species, *Dictyota naevosa* and *Stypopodium lobatum*. The grass-like *Caulerpa ligulata* is found in pools and under ledges, and in one case forms a large field on a sand-bank just offshore. The soft dark green tufts of *Callithamnion stuposum* are also a feature of the seaward parts. *Laurencia obtusa* is common as at Still Bay, and there are again several corallines (*Amphiroa ephedraea*, *A. Bowerbankii*, *Corallina Cuvieri* and other species). In pools there are species of *Sargassum*, probably including the two common at Still Bay as well as a third; and a brown fan-like weed, *Zonaria interrupta*. Lithothamnia are abundant, but often of comparatively poor growth; but they become well developed and often highly coloured under stones and in some of the pools.

The fauna of the open rock is largely a repetition of that of Still Bay, and the same applies in part to the fauna of the pools. The highest parts of the rocks support the usual forms of higher levels, such as *Chthamalus dentatus*, *Patella granularis*, *Siphonaria capensis*, *S. deflexa*, etc. On somewhat lower parts *Siphonaria capensis* and *Patella longicosta* appear to be the dominant limpets, though *P. barbara* and *P. miniata* are also common. As at Still Bay, *Siphonaria capensis* and *S. deflexa* are both very abundant at the higher levels, but *S. capensis* appears to be the prevalent species lower down. The same species of *Oxystele*, *Cominella*, *Turbo* and *Littorina* are prevalent as at Still Bay; and *Acanthochiton turtoni* and the crabs *Plagusia chabrus* and *Cyclograpsus punctatus* are common. *Pomatoleios crosslandi*, though common, is often rather poorly developed, and flourishes less well than at Still Bay. The Cochlear zone is present, but in a somewhat modified form. The seaward rocks, which are frequently separated from one another by fairly deep channels, bear patches (of, for instance, 1–2 square feet) of *Patella cochlear*, which commonly present a curious honeycombed appearance, due to the fact that the limpets, which are on the average smaller than usual, inhabit depressions in the soft rock, and have become flattened or even concave in shape, in adaptation to their hollows. The other limpets common on the lower parts of the shore (especially in the case of *P. barbara*) have the same tendency to inhabit hollows. On the lowest rocks large Pyurid ascidians are common, but at the tides available to us we were unable to determine whether or no they assume the mass-formation most typical of the Pyura community.

4. *The cryptofauna of the boulders.* Judging from the account so far given, the fauna of the Preekstoel rocks might be taken to be somewhat poor in species. Its real richness is only revealed when the boulders lying in pools and crevices are turned over; here the variety is great. The following list will give some idea of the general content of this fauna.

Foraminifera. The prickly red *Polytrema miniaceum* is characteristic of this habitat.

Sponges are represented by various species, often of brilliant colours. Some rounded pea-like forms are common.

Anthozoa. The gorgonian *Eunicella papillosa* is common, so is the small *Alcyonium fallax*, whose polyps are usually brilliant violet in colour, but sometimes yellow. A species of *Isozoanthus* with red tentacles is also plentiful.

Polychaeta. The prevalent worms include *Gunnarea capensis* and *Nicolea macrobranchia*; but many species are present.

Echinodermata. The common forms include the many-coloured urchin *Parechinus angulosus*; three species of holothurians, the black *Cucumaria sykion*, the whitish or brownish *Colochirus doliolum*, and a handsome red species (*Stichopus grammatus*), which is locally plentiful on the sand under boulders. The asteroids include the ubiquitous *Asterina exigua* and the scarlet *Parasterina bellula.* There are also many ophiuroids.

Brachiopoda. The rose-coloured *Kraussina rubra* is common.

Polyzoa. There are several encrusting forms, together with a common species with erect calcareous branches, much resembling a small coral (*Costazia costazii*).

Mollusca. Several small species of gastropod are plentiful, including fissurellids; and there are a great many specimens of the mussel *Barbatia obliquata. Chiton tulipa* and *Ischnochiton tigrinus* are common.

Crustacea. Isopods and amphipods are abundant.

Ascidians. Simple ascidians are to be found, together with compound species of various colours, including *Symplegma elegans* with crimson or yellow zooids; Didemnids; and other forms.

5. *The isolated outcrops.* One of the isolated rocky masses at the Still Bay end of the tract deserves separate description. This mass is higher than the others, and its seaward edge is abrupt, creating a considerable splash where it meets the surf. The top of the rock is coloured red-brown by algae (principally *Gelidium pristoides, Caulacanthus ustulatus* and *Splachnidium rugosum*). Part of the outcrop is covered by sheets of *Mytilus perna*, and there are patches of *Ulva Lactuca* (also present in pools) and of *Enteromorpha.* Round the seaward edge of the rock are lower ledges and surfaces upon which patches of the *Patella cochlear* community (much overgrown by microphytes) occur, containing *P. cochlear, P. longicosta* and *P. barbara*, together with the algae *Laurencia flexuosa* and *Hypnea spicifera*—the latter a handsome deep blue-green in colour, although technically a "red" alga. The large leathery ascidian *Pyura stolonifera*

occurs in mass-formation on the lowest rock-faces, the individuals tightly packed; in other words, the sublittoral Pyura community is here typically developed. Both on the outcrop and on rocks to landward of it are oysters (*Ostrea iridescens*).

Discussion.

It will have been noted that in this paper the population of the intertidal belt is described in very general terms. We have given such precision to the description as the nature of the investigation permits; but have not yet had an opportunity of making detailed measurements by means of traverses (of the type made, for instance, by Colman at Wembury, 1933), of analysing the population fully into its constituent communities, or of classifying the organisms into categories such as dominant, sub-dominant, and so forth. We hope to do this in due course. Meanwhile, knowledge of the South African shores is far behind that of the European area; and the types of work mentioned can be undertaken more satisfactorily after a preliminary survey of a locality has been completed. We feel it advisable to proceed from the general to the particular.

Zonation. In the absence of exact measurements, we cannot give the precise relationship between the three broad zones we have described and the tidal levels; but the position is approximately as follows. The Balanoid zone is the belt at least part of which is submerged and exposed every day; the Cochlear zone is not exposed by the weaker tides, but emerges to a greater or lesser extent at the stronger ones; and the Littorina zone is not more than partly submerged or wetted by the weaker tides, and not completely submerged or wetted at spring tides, unless in maximal cases.

The Littorina zone, therefore, lies chiefly in the littoral belt, but overlaps into the supralittoral. The Balanoid zone is wholly littoral. The Cochlear zone, although submerged at low water of neaps, is exposed at low water of springs, and we should classify it definitely as littoral. In our view the upper edge of the Pyura community marks the beginning of the sublittoral. This agrees partly, but not wholly, with Gislen's usage of the terms in question (1930, p. 48), and we will return to a fuller treatment of the subject when more of the South African coast has been described.

Comparison of Still Bay with a British shore. It will be possible later on to subdivide the South African intertidal region into a more detailed series of zones than the ones mentioned, by taking particular organisms as standards of reference, in the usual way; and this zonation should present an interesting contrast to that of European shores. In South Africa a convenient series of Fucoids, such as is found on the British coasts, does not exist. The similar Sargassa, which are in any case difficult to identify,

do not appear to form a particularly favourable subject for studies in zonation; but another member of the Fucales, *Bifurcaria brassiciformis*, is serviceable in this connection, though of limited distribution. The red algae, moreover, are more inclined in these latitudes to emerge on to the open rock at fairly high levels than in the British region; and the arrangement of *Ulva* and *Enteromorpha*, when studied in detail, may prove to be different. The zonation of the algae, however, has been worked out in some detail by Dr. W. E. Isaac, and until his papers have appeared further comment is unnecessary. Among animals, the existence in South Africa of several species of limpets, not present in Britain, offers one means of subdivision into zones, since these animals, although they move about to a certain extent, are relatively sedentary forms. Mytilids, balanoids, and sedentary polychaets, whelks and periwinkles, will also prove useful.

The coast at Still Bay is fundamentally unlike many typical British shores in lacking a Laminarian zone. Such a zone is by no means absent in South Africa as a whole; but in its full development it appears to be restricted to the colder waters. Where it does occur in full force it far surpasses that of the British seas in the size of the dominant Laminarians, *Ecklonia buccinalis*, *Laminaria pallida* and *Macrocystis pyrifera*. The stipes of the *Ecklonia* (not including the fronds) commonly exceed 20 feet (6 metres) in length (fig. 7), and those of *Macrocystis* may be longer still. Along the Atlantic coast of the Cape Peninsula the Laminarian zone and the Cochlear zone co-exist; but generally speaking the upper limit of the Cochlear zone is distinctly higher up than that of the Laminarian.

Despite the absence of a Laminarian zone, however, there are many resemblances between the temperate Indian Ocean shore, as exemplified by Still Bay, and a British coast. We find similar small periwinkles at high levels (*Littorina knynaënsis* instead of *L. neritoides* and *L. saxatilis*); similar fields of barnacles and mussels (though belonging to different species); limpets are common; there are masses of worm tubes (*Pomatoleios* and *Gunnarea*, the latter closely allied to *Sabellaria*); there are a number of common snail-like gastropods exhibiting a definite zonation; corallines are prevalent in suitable habitats; there is, of course, the same increasing richness of fauna as one proceeds to regions of less and less exposure; and other parallels can be drawn. This comparison will be worked out in fuller detail when further information is available.

Still Bay and False Bay. An ecologist working on the False Bay coast of the Cape Peninsula, especially at the St. James end, is at once struck with the general resemblance between the biota of this region and that which has been described for Still Bay. In spite of the general resemblance, however, certain differences are at once apparent, and among them are the following. On many of the higher rocks of the St. James region,

Porphyra is to be found in great quantity. At lower levels the substratum is often thickly coated with leafy Rhodophyceae of moderate size, dark brown in colour—*Chaetangium ornatum*, *Gigartina radula* and *G. stiriata*. Prominent Phaeophyceae are the whip-like *Bifurcaria brassicaeformis* and

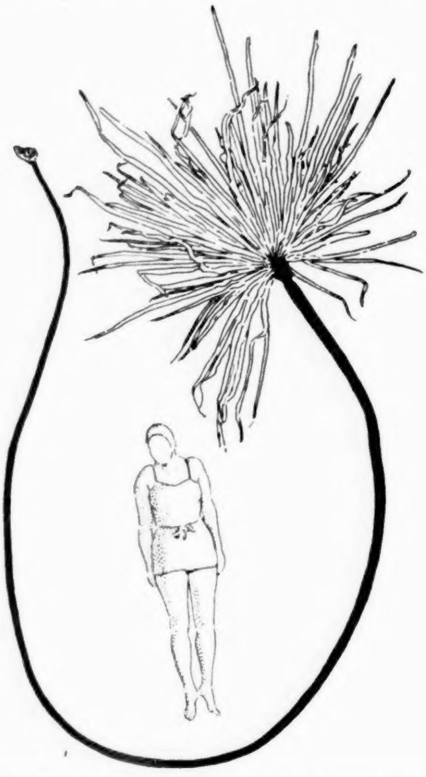

FIG. 7.—A sketch showing the relative sizes of a human figure 5 ft. 4 in. (1·6 m.) high, and a specimen of *Ecklonia buccinalis*. The stipe of the *Ecklonia* was 27 ft. 2 in. (8·3 m.) long; the fronds up to 5 ft. 7 in. (1·7 m.); making, with the addition of the holdfast and the expansion bearing the fronds, a total of about 33 ft. 8 in. (10·3 m.). Traced from a photograph.

the more shrub-like *Pycnophycus laevigatus*. The red sponge *Hymeniacidon sanguinea* is strikingly abundant, often forming large masses. The limpet *Patella granatina* and the mussel *Mytilus crenata*, although much more abundant in the colder water, are not uncommon at St. James. There are other contrasts which will be dealt with in a later publication. During the second visit to Still Bay and Preekstoel in 1935 a special search was made

for the organisms just mentioned. Most of them could not be found at all: *Hymeniacidon* and *Porphyra* were found in small quantities; and a few very young plants of a *Gigartina* similar to *G. radula*; but none of these had the ecological importance that they possess at St. James. Our later studies of the coast at other localities suggest that most of these contrasts are not merely local variations, but are significant differences connected with temperature.

In comparing the algal flora of one region with that of another, seasonal variation must naturally be taken into account. So far as our study of the Peninsula enables us to judge, however, the seasons affect not so much the presence or absence of the larger algae, as their luxuriance, where effective at all. Perhaps the most noticeable variation is that of *Porphyra*, as exemplified during 1935 at St. James. It was scanty during the early part of the year (summer), flourished during the winter, changing colour and becoming reduced as the next summer approached. Since Still Bay was visited once in summer and once at the end of winter, probably a fair conception of the algal flora was obtained; but between the two visits there were unexpected differences. In January 1932 *Stypopodium lobatum*, *Ulva Lactuca*, *Splachnidium rugosum* and *Dictyota naevosa* were all fairly common; in September 1935 only the latter could be found, and it was not common. Again, certain species (*Laurencia virgata*, *Codium Stephensiae*, and a species probably belonging to the genus *Colpomenia*) were much more plentiful in 1935 than in 1932. It is difficult to attribute these differences to any seasonal effect, since in the Peninsula at least, such of these species as are present at all are usually to be found at any time of year.

The relationships of the Still Bay flora and fauna. The composition of the marine fauna of South Africa in general, and of Still Bay in particular, has been discussed in recent systematic papers dealing with some of the animal groups. We propose to study this question in some detail, but as an analysis of the Still Bay fauna and flora will necessarily involve comparison with those of other places on the coast, we prefer to deal with it in a separate paper after the remaining general surveys have been completed. Meanwhile, the following paragraphs, though subject to revision, will indicate the state of affairs so far revealed.

Isipingo, near Durban, presents the curious picture of a place well outside the tropics, and not at the present time beset by coral reefs; but whose shore, nevertheless, supports a limited number of species of reef-corals, occurring in moderate numbers on a substratum of sandstone, and inhabiting rock-pools. Accompanying the corals are various algae and animals common on coral-reefs. Conspicuous examples of these are the echinoderms *Echinostrephus molare*, *Tripneustes gratilla*, *Echinometra mathaei*, *Diadema setosa*, *Stomopneustes variolaris*, *Holothuria cinerascens*

and *H. vagabunda;* species of zoanthids which form extensive carpets; the crab *Grapsus strigosus*; and species of *Halimeda* and *Caulerpa*. Apart from these tropical species, however, there occur at Isipingo forms which belong to the Cape fauna, and some of which extend into the coldest water of the South African coast. At Isipingo, therefore, the influence of the Moçambique current is strong, and the intertidal fauna and flora are intermediate between those of a coral-reef and a temperate shore, and may be described as sub-tropical.

At Still Bay the influence of the warmer water is very much less marked than at Durban. The fauna and flora here are not free from tropical elements; but these elements are not sufficiently in evidence to affect the general appearance of the shore; the reef-corals, the conspicuous tropical echinoderms and sheets of zoanthids, and similar features, have disappeared altogether, and the locality has no resemblance to a coral-reef. This in itself would make the proportion of Cape species higher at Still Bay than at Durban, but in addition a number of Cape forms are present at Still Bay, which do not extend as far as Durban. On the other hand, our surveys so far indicate that, if Still Bay be compared with False Bay, the proportion of tropical species present in the latter area will be lower than in the former, and the proportion of cold-loving species higher. In other words, Still Bay represents, in our series, a place not markedly affected by either the warmest or the coldest water; a place with a temperate sea-climate, but a climate lying towards the warmer end of the temperate scale.

From the Cape of Good Hope northward, along the west coast to Port Nolloth, a great change is observed. Not only does the personnel of the fauna and flora partly change, but the whole appearance of the shore is altered by the presence of large algae in great abundance, and there is a strongly developed Laminarian zone dominated by one or all of the three huge plants *Laminaria pallida, Ecklonia buccinalis* and *Macrocystis pyrifera*. This contrasts with the east coast in general, so far as we know it, where large algae are notably scarce, and where a Laminarian zone is absent save in particular areas controlled by special conditions (*e.g.* Hermanus), or exists only in a reduced form, with a population of the small *Ecklonia radiata* (as at East London). From Cape Town to Port Nolloth, although the change in temperature is not marked, there are changes in the fauna and flora, such as a transition from the dominance of *Ecklonia* over *Laminaria* in the south, to that of *Laminaria* over *Ecklonia* in the north *; but, speaking generally, the difference between Cape Town and Port Nolloth is very much less than that between Cape Town and Durban.

The content of the above paragraphs may suitably be amplified by a

* This applies to the part of the Laminarian zone visible from the shore; whether it applies to the deeper part of the zone cannot yet be stated.

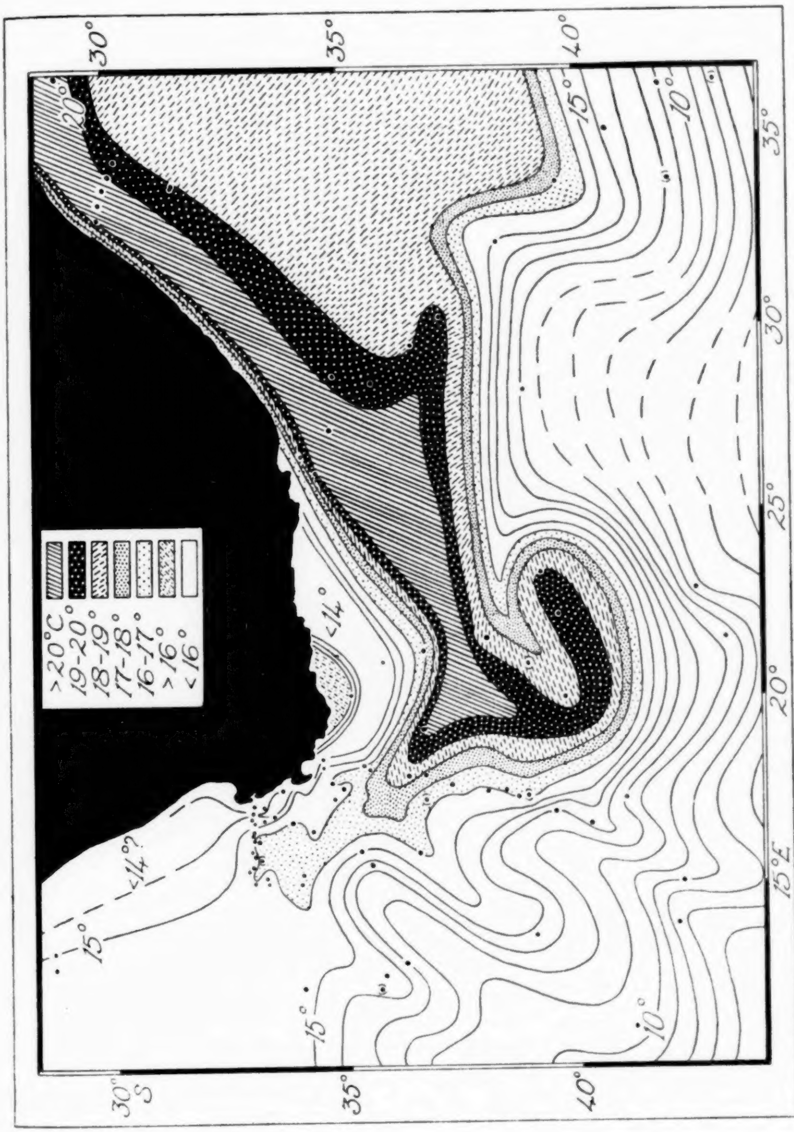

FIG. 8.—A diagram giving an indication of the distribution of water of different temperatures, at a depth of 50 m., off the South African coast, the available data adjusted so as to apply to the month of October. Modified from Dietrich, 1935, p. 38, Abb. 25. This diagram is not intended to show details of the temperature close inshore.

definite example of species-distribution on the South African coast. As has already been mentioned, special attention is being paid to the distribution and bionomics of the Patellidae. The statement which follows is based principally upon the surveys so far completed, and the evidence supporting it, which is in part quantitative, will be published elsewhere. The situation revealed indicates that there are at least twelve species belonging to the genera *Patella* and *Cellana*, which are common on the South African coasts.* Ten of these are common in the Cape Peninsula, though with distinct differences in the relative abundance of some of the species, on the warmer and the colder sides. Proceeding eastwards from the Peninsula, eight of these ten species are present (and most of them common), in the Still Bay area, the two which we have not found there being *P. granatina*, a species flourishing best in the colder water, and *P. compressa*, also a cold-water form living on *Ecklonia buccinalis*. At Durban, only three of the Peninsula species appear to be at all common (*P. barbara*, *P. longicosta* and *P. granularis*); but in addition two species which do not, so far as we know, reach Still Bay or the Peninsula (unless as rarities) are abundant (*Cellana capensis* and *C. variabilis*). Proceeding from the Peninsula along the west coast, we find that at Port Nolloth seven of the ten species are present (and mostly common), and of the apparent absentees two (*P. oculus* and *P. longicosta*) are peculiarly notable, since they are species flourishing best on the warm-temperate part of the coast and becoming scarce in the colder water. It may further be noted that only two of the species mentioned, *P. granularis* and *P. barbara*, appear to be common round the whole coast from Port Nolloth to Durban; and even these show a difference in average *size* as between warmer and colder parts of the coast. Summarising this information as it affects Still Bay, it may be said that Still Bay lacks those species of *Patella* and *Cellana* which appear to reach their optimum on either the warmest or the coldest parts of the coast, but possesses all the others, and notably a strong representation of the two warm-temperate species *P. oculus* and *P. longicosta*.†

* We are aware that more than twelve species have been described from South Africa: but some at least of these species are invalid. The synonymy of the forms involved will be discussed in due course. Moreover, records referring to beach-washed shells must necessarily be treated with reserve, or even ignored, in determining the actual distribution of the species. The information given here refers to populations of living animals quantitatively observed. The classification which we have adopted in consultation with Mr. Tomlin, for the Patellidae referred to in this paper, is as follows: In the genus *Patella* are included the species *argenvillei*, *barbara*, *cochlear*, *compressa*, *granatina*, *granularis*, *longicosta*, *miniata*, *oculus*, and *patriarcha*; in the genus *Cellana* the species *capensis* and *variabilis*; and in the genus *Helcion* the species *pectunculus* and *pruinosa*.

† In this paragraph no mention is made of the two common species of *Helcion* (*H. pectunculus* and *H. pruinosa*), since we are not yet in a position to indicate their distribution.

The influence of factors other than temperature. After the descriptive parts of this series of papers are completed, we hope to make an attempt to differentiate between the effects of temperature and the influence of other environmental factors on the distribution of species round the South African coast. We are at present taking the probability that the (horizontal) distribution observed is connected to a considerable extent with temperature as a working hypothesis: but we are fully aware that other influences are operative in the intertidal zone, and hope to discuss them in due course.

Summary.

This paper is the first of a projected series, dealing with the rocky part of the South African intertidal zone, in which the effects of the warm Agulhas current on the one hand, and of the cold Antarctic water on the other, are being studied. The ecology of two intertidal areas near Still Bay, on the coast of the Indian Ocean, east of Cape Agulhas, is described. The fauna and flora of these areas gives a picture of a temperate region, probably influenced by the warm current, but certainly much less strongly so than the coast near Durban; and still containing a limited number of tropical species, while including at the same time Cape species which do not extend as far north as Durban. The shore is described as being divided into three principal zones—the Littorina zone, which is not fully submerged at ordinary spring tides; the Balanoid zone, at least part of which is covered and uncovered every day; and the zone of *Patella cochlear*, which is uncovered only at spring tides. No Laminarian zone is present, and the uppermost belt of the sublittoral region is partly characterised by the presence of large simple ascidians (*Pyura stolonifera*). The shore is compared briefly with the British intertidal region, and with other parts of the South African littoral. The Still Bay region is peculiarly intermediate between a tropical region, in which the sublittoral belt is occupied by corals, and a cold-temperate shore in which the same zone is occupied by Laminarians. The Still Bay algal flora is notably deficient in plants of large size, and the shore possesses no zone of "bulky sedentary oxygen-producing organisms" at its seaward fringe, as in the other two cases mentioned.

Acknowledgment.

In addition to acknowledgments made in the text, we wish to thank Miss K. M. F. Bright for the photograph reproduced as Pl. XXI, fig. 1; Mons. A. Blahovsky for that used for Pl. XX: and Messrs. Taeuber & Corssen for Pl. XXI, fig. 2.

Annotated List of Plants and Animals Collected at Still Bay and Preekstoel.

In the following list the names are arranged in alphabetical order under the groups to which they belong; but the names of the groups are arranged in systematic order. The presence of an asterisk (*) beside a name indicates that the organism designated is either fairly or very common. The absence of an asterisk does not necessarily mean that the organism in question is rare, but that we are not yet in a position to say whether it is rare or common. An attempt has been made to differentiate the surface-fauna from the fauna under stones, by marking the forms collected from the undersides of stones with a dagger (†); but it must be remembered that some of these forms may occur in other situations as well, and also that some of the surface-forms occur quite commonly beneath stones as well as in exposed places; there *is* a distinction between cryptofauna and surface-fauna, but it is not absolute. Moreover, some forms inhabit crevices during the day and appear on the surface at night. No distinction has been made in the list between Morris Point and Preekstoel, since such differences as exist between the two places are probably of no more than local importance.

ALGAE.

Myxophyceae.

* *Lyngbya semiplena* (Ag.) J. Ag.

Chlorophyceae.

* *Caulerpa ligulata*, Harv.
* *Cladophora sp.*
* *Codium Stephensiae*, Dickinson.
* ,, *Duthiae*, Setch.?.
* *Enteromorpha spp.*
Letterstedtia insignis, Aresch.
* *Ulva Lactuca*, Linn.

Phaeophyceae.

* *Colpomenia sp.*
Dictyota Fasciola (Roth) Lam.
* ,, *liturata*, J. Ag.
* ,, *naevosa* (Suhr) J. Ag.
Ectocarpus sp.
Endarachne Binghamiae, J. Ag.
* *Lepadoderma africanum*, Dickinson.
Myriocladia Sciurus, Harv.
Phloiocaulon squamulosum (Suhr) Geyler ?.

Phaeophyceae.

* *Sargassum heterophyllum* (Turn.) Ag.
* ,, *incisifolium* (Turn.) Ag.
(and perhaps other species).
* *Splachnidium rugosum* (Linn.) Grev.
* *Stypopodium lobatum*, Ktz.
* *Zonaria interrupta* (Lam.) J. Ag.

Rhodophyceae.

Corallinaceae.

* *Amphiroa Bowerbankii*, Harv.
* ,, *ephedraea* (Lamk.) Decn.
* *Cheilosporum cultratum* (Harv.) Aresch.
* ,, *flabellatum* (Harv.) Aresch.
Corallina Cuvieri, Lam.
* ,, *flabellata*, Ktz.
* ,, *spp.*
* *Jania natalensis*, Harv.
* ,, *sp.*
(Lithothamnia were also collected, but no identifications have so far been received.)

Non-Calcareous Forms.

* *Bostrychia mixta*, Hook. and Harv.
Calliblepharis fimbriata (Ag.) Ktz.
* *Callithamnion stuposum*, Suhr.
* *Caulacanthus ustulatus* (Mert.) Ktz.
Chondrococcus Hornemanni (Mert.) Schmitz.
* *Gelidium pristoides* (Turn.) Ktz.
* *Hildenbrandtia pachythallos*, Dickinson.
* *Hypnea spicifera* (Suhr) Harv.
* *Laurencia flexuosa*, Ktz.
* ,, *obtusa* (Huds.) Lam.
* ,, *virgata* (Ag.) J. Ag.
* *Plocamium corallorhiza* (Turn.) Harv.
* ,, *membranaceum*, Suhr?.
* *Polysiphonia spp.*
Porphyra capensis, Ktz.

ANIMALS.

Foraminifera.

†* *Polytrema miniaceum*, Pallas.

PORIFERA.

CALCAREA.

† *Heteropia glomerosa* (Bowerbank).
† *Leucosolenia cerebrum* (Haeck.).
† ,, *coriacea* (Montagu).
† *Sycon ciliatum* (Fabr.).
†* ,, *gelatinosum* (Blainv.).
† ,, *kerguelensis*, Hentschel.
† ,, *munitum*, Jenkin.

TETRAXONIDA.

† *Adocia simplicissima*, Burton.
†* *Chondrosia reniformis*, Schmidt.
†* *Ciocalypta oculata*, var. *maxima*, Hentschel.
† *Forcepia agglutinans*, Burton.
† *Geodia littoralis*, Stephens.
† *Haliclona ciocalyptioides*, Burton.
†* ,, *stilensis*, Burton.
Hymeniacidon sanguinea (Grant).
† *Lissodendoryx sinensis*, Brönsted.
†* *Oscarella lobularis* (Schmidt).
† *Polymastia mammillaris* (Müller).
† *Stelletta grubei*, Schmidt.
† ,, *grubioides*, Burton.
† *Suberites stilensis*, Burton.
† *Tethya diploderma*, Schmidt.
† ,, *lyncurium*, Pallas.
† *Tetilla cranium* (Müller).

EUCERATOSA.

†* *Aplysilla rosea*, Schulze.
† *Hippospongia frondosa*, Hentschel.
† *Hircinia aruensis*, Hentschel.
† *Spongelia cineria* (Keller).
† ,, *fragilis* (Montagu).

COELENTERATA.

HYDROZOA.

† *Halecium sp.*, aff. *beani*, Johnston.
†* *Kirchenpaueria unilateralis* (Ritchie).
†* *Schizotricha simplex*, Warren.
†* *Sertularella tenella* (Alder).

SCYPHOZOA.

† *Lipkea stephensoni*, Carlgren.

COELENTERATA.

ALCYONARIA.

†* *Alcyonium fallax*, Lüttschwager.
†* *Eunicella papillosa* (Esper) Hickson.

ACTINIARIA.

* *Actinia tenebrosa*, Farquhar?.
* *Anthopleura michaelseni* (Pax).
Bunodactis reynaudi (M. Edw.).
Bunodosoma capensis (Lesson).
†* *Anthothoe stimpsonii* (Verr.)?.
* *Pseudactinia flagellifera* (Hertwig).

MADREPORARIA.

Balanophyllia annae, van der Horst.

ZOANTHINARIA.

†* *Isozoanthus capensis*, Carlgren.

TURBELLARIA.

† *Leptostylochus sp.*?.
†* *Notoplana ovalis*, Bock.
†* *Planocera gilchristi*, Jacubowa.
† *Planocerodes ceratommata*, Palombi.
Prosthiostomum siphunculus (D. Ch.).
Stylochoplana tenuis, Palombi.

NEMERTINEA.

†* *Lineus corrugatus*, McIntosh.

POLYCHAETA.

AMPHINOMORPHA.

† *Euphrosyne capensis*, Kinberg.

NEREIMORPHA.

† *Arabella mutans* (Chamberlin).
† *Bhawania cryptocephala*, Gravier.
† *Eulalia sp.*
† *Eunice filamentosa*, Grube.
† *Harmothoe aequiseta*, Kinberg.
† ,, *waahlii* (Kinberg).
†* *Lepidonotus semitectus*, Stimpson.
† *Lysidice capensis*, Grube.
† *Perinereis capensis* (Kinberg).
† ,, *falsovariegata*, Monro.
† *Polynoe scolopendrina*, Savigny.

POLYCHAETA.

NEREIMORPHA.

† *Syllis brachychaeta*, Schmarda.
† ,, *variegata*, Grube.
† *Trypanosyllis zebra*, Grube.

DRILOMORPHA.

Audouinia filigera (D. Ch.).
†* var. *capensis* (Schmarda).
† var. *meridionalis* (Marenz.).
† *Clymene lumbricoides*, Quatr.
† ,, *praetermissa* (Malmgren), var. *capensis*, McIntosh.

TEREBELLOMORPHA.

†* *Nicolea macrobranchia* (Schmarda).
† *Thelepus plagiostoma* (Schmarda).

SERPULIMORPHA.

† *Branchiomma quadrioculatum*, Willey.
* *Gunnarea capensis* (Schmarda).
† *Hydroides spinosus* (Pixell).
* *Pomatoleios crosslandi*, Pixell.
† *Sabellastarte longa* (Kinberg).
† *Serpula vermicularis*, Linn.
†* *Spirorbis sp.*

GEPHYREA.

A few of these were collected, but no identifications have so far been received. They occur under stones, inside the rock at Preekstoel, etc.

POLYZOA.

STENOLAEMATA.

† *Lichenopora verrucaria* (Fabr.).

GYMNOLAEMATA.

†* *Chaperia stephensoni*, O'Don. and de Watt.
†* *Costazia costazii* (Sav. and Aud.), var. *erecta*, O'Don. and O'Don.
† *Cribrilina simplex*, O'Don. and de Watt.
† *Holoporella capensis*, O'Don. and de Watt.
† *Rhyncozoon fulgidum*, O'Don. and de Watt.
† ,, *longirostre* (Hincks).
† *Schizoporella cecilii* (Aud. and Sav.).
† ,, *tenuis*, Busk.
† *Steganoporella magnilabris* (Busk).

BRACHIOPODA.

†* *Kraussina rubra* (Pallas).

CRUSTACEA.

CIRRIPEDIA.

Balanus amphitrite, Darwin.
* *Chthamalus dentatus*, Krauss.
* *Octomeris angulosa*, Sow.
* *Tetraclita serrata*, Darwin.

TANAIDACEA.

Tanais spongicola, Barnard.

ISOPODA. (Isopoda and Amphipoda not marked with a dagger (†) were collected from seaweed.)

† *Accalathura sp.*
†* *Cirolana cranchii*, Leach.
†* ,, *venusticauda*, Stebb., var. *simplex*, Barnard.
* *Cymodocella pustulata*, Barnard.
Dynamenella huttoni (Thomson).
,, *ovalis*, Barnard.
†* *Exosphaeroma kraussii*, Tattersall.
†* *Glyptidotea lichtensteini* (Krauss).
†* *Janira capensis*, Barnard.
* *Janiropsis palpalis*, Barnard.
* *Ligia natalensis*, Collinge.
Paridotea fucicola, Barnard.
† *Parisocladus stimpsoni* (Heller).
† *Stenetrium saldanha*, Barnard.
†* ,, *spp.*

AMPHIPODA.

Ampithoe falsa, Barnard.
Aora typica, Kröyer.
†* *Ceradocus rubromaculatus* (Stimpson).
†* *Elasmopus boekii* (Haswell).
* ,, *pectenicrus* (Bate).
Gitanopsis pusilla, Barnard.
* *Hyale grandicornis* (Kröyer).
Ischyrocerus anguipes, Kröyer.
Lysianassa ceratina (Walker).
* *Macropisthopous stebbingi*, Barnard.
†* *Melita inaequistylis* (Dana).
† *Paramoera bidentata*, Barnard.
†* ,, *capensis* (Dana).

CRUSTACEA.

AMPHIPODA.

† *Parelasmopus suluensis* (Dana).
Podocerus africanus, Barnard.
,, *palinuri*, Barnard.
† *Polycheria atolli*, Walker.
†* *Temnophlias capensis*, Barnard.

CARIDEA.

* *Leander pacificus*, Stimpson.

ANOMURA.

* *Diogenes brevirostris*, Stimpson.
Upogebia capensis (Krauss).

BRACHYURA.

* *Cyclograpsus punctatus*, M. Edw.
† *Dehaanius dentatus* (M. Edw.).
† *Leucisca squalina*, McLeay.
* *Plagusia chabrus* (Linn.).

ARACHNIDA.

PYCNOGONIDA.

† *Böhmia chelata* (Böhm).

ARANEIDA.

* *Desis tubicola* (Pocock).

INSECTA.

* *Telmatogeton minor*, Kieffer.

MOLLUSCA.

LAMELLIBRANCHIATA.

†* *Barbatia obliquata* (Wood).
† *Chlamys tincta* (Reeve).
† *Kellia rotunda*, Deshayes.
† *Lasaea turtoni*, Bartsch.
† *Lepton fortidentatum*, Smith.
† *Monia, sp.*
* *Mytilus perna* (Linn.).
* *Ostrea iridescens*, Gray.
†* *Thecalia concamerata* (Brug.).

AMPHINEURA.

* *Acanthochiton turtoni*, Ashby.
† *Callochiton castaneus* (Wood).
† *Chaetopleura pertusus* (Reeve).

MOLLUSCA.

AMPHINEURA.

†* *Chiton tulipa*, Q. and G.
†* *Ischnochiton elizabethensis*, Pilsbry.
†* ,, *tigrinus* (Krauss).

PROSOBRANCHIATA.

†* *Assiminea umlaasiana*, Smith.
* *Cominella cincta* (Röding).
† ,, *elongata* (Dunker).
†* ,, *tigrina* (Kiener)?.
† *Conus aurora*, Lamarck.
Diodora elevata (Dunker).
* ,, *mutabilis* (Sowerby).
,, *spreta* (Smith).
† *Drillia grayi* (Reeve).
† *Eulima algoensis*, Smith.
†* *Gibbula cicer* (Philippi).
† *Haliotis alfredensis*, Bartsch.
†* ,, *sanguinea*, Hanley.
* *Helcion pectunculus* (Gmelin).
* ,, *pruinosa* (Krauss).
† *Leptothyra quantilla* (Gould).
† ,, *rotundata* (Sowerby).
* *Littorina knysnaënsis*, Philippi.
† *Mitra capensis*, Reeve.
† ,, *merula*, Sowerby.
† ,, *patula*, Reeve.
† *Nassarius kraussianus* (Dunker).
† *Ocenebra scrobiculata* (Philippi).
* *Oxystele sinensis* (Gmelin).
* ,, *tigrina* (Dillwyn).
* ,, *variegata* (Anton).
* *Patella argenvillei*, Krauss.
* ,, *barbara*, Linn.
* ,, *cochlear*, Born.
* ,, *granularis*, Linn.
* ,, *longicosta*, Lamarck.
* ,, *miniata*, Born.
* ,, *oculus*, Born.
,, *patriarcha*, Pilsbry.
†* *Tricolia bicarinata* (Dunker).

MOLLUSCA.

PROSOBRANCHIATA.

† *Tricolia kochi* (Philippi).
† *Seila africana*, Bartsch.
Thais capensis (Petit).
†* ,, *castanea* (Küster).
* ,, *dubia* (Krauss).
† *Triphora africana*, Bartsch.
* *Turbo cidaris*, Gmelin.
* ,, *sarmaticus*, Linn.
† *Turbonilla kraussi*, Clessin.

TECTIBRANCHIATA.

†* *Berthella granulata* (Krauss).
†* *Pleurobranchus sp.*

NUDIBRANCHIATA.

Dendrodoris kalkensis (Barnard).
† *Glossodoris capensis*, Barnard.
† *Hervia quadricolor*, Barnard.
† *Polycera nigrocrocea*, Barnard.
† *Triopa lucida*, Stimpson.

PULMONATA.

* *Siphonaria capensis*, Q. and G.
* ,, *deflexa* (Helbling).
,, *oculus*, Krauss.

ECHINODERMATA.

CRINOIDEA.

†* *Comanthus wahlbergii* (J. Müller).

ASTEROIDEA.

* *Asterina exigua* (Lamk.).
* *Echinaster ornatus*, Perrier.
* *Marthasterias glacialis* (Linn.), var. *rarispina* (Perrier).
* *Parasterina bellula* (Sladen).

OPHIUROIDEA.

† *Amphioplus integer* (Ljungman).
† *Amphipholis squamata* (D. Ch.).
†* *Amphiura capensis*, Ljungman.
† *Ophiactis carnea*, Ljungman.
†* *Ophiarachnella capensis* (Bell).
†* *Ophionereis dubia* (Müll. and Trosch.).
†* *Ophiothrix triglochis*, Müll. and Trosch.

ECHINODERMATA.

ECHINOIDEA.

* *Parechinus angulosus* (Leske).

HOLOTHUROIDEA.

†* *Colochirus doliolum* (Pallas).
† *Cucumaria frauenfeldi*, Ludwig.
†* „ *sykion* (Lampert).
†* *Stichopus grammatus* (H. L. Clark).

ASCIDIACEA.

† *Amaroucium erythraeum*, Mich.
† *Ascidia incrassata*, Heller.
† „ *sydneiensis*, Stimps.
† *Botryllus sp.*
† *Didemnum stilense*, Mich.
† „ *velans*, Mich.
† (and other Didemnids).
†* *Distaplia capensis*, Mich.
† „ *sp.*
† *Leptoclinides capensis*, Mich.
†* *Microcosmus oligophyllum*, Heller, var. *wahlbergi*, Mich.
* *Pyura stolonifera* (Heller).
† *Sigillina coerulea* (Sluiter)?.
†* „ *rhodopyge* (Sluiter), forma *kauderni* (Mich.).
†* *Styela stephensoni*, Mich.
†* *Symplegma elegans* (Q. and G.).

PISCES.

(All collected in pools.)

Chaetodon marleyi, Regan.
* *Chorisochismus dentex* (Pallas).
* *Clinus superciliosus* (Linn.).
Gobius melanocephalus, Bleeker.
* „ *nudiceps*, Cuv. and Val.
Pomatomus saltator (Linn.).
* *Tetrodon honckeni*, Bloch.

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This list includes only papers referred to in the text. A full list of systematic and oceanographical works dealing with South Africa will appear in a later paper. Papers marked with an asterisk refer to observations or material collected in connection with the University of Cape Town's Ecological Survey.

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The intertidal zone in South Africa: typical conditions. From a photograph by A. Blahovsky.

T. A. Stephenson. *Neill & Co., Ltd.*

FIG. 1.—The sublittoral fringe, False Bay. Rocks densely coated with the ascidian *Pyura stolonifera*. Note the absence of large algae. From a photograph by K. M. F. Bright.

FIG. 2.—The Cochlear zone, False Bay. Most of the limpets shown are specimens of *Patella cochlear*. The principal alga visible is *Splachnidium rugosum*. From a photograph by Messrs. Taeuber and Corssen.

T. A. Stephenson. *Neill & Co., Ltd.*

The Balanoid zone, Still Bay. *Tetraclita serrata* and *Chthamalus dentatus* on the sheltered side of a rocky ledge. The *Tetraclita* is the larger of the two species. From a photograph by T. A. Stephenson.

The Cochlear zone, False Bay; detail. The rock is extensively coated with lithothamnion. The limpets are all specimens of *Patella cochlear*. The dark fringe surrounding each limpet is a low browsed mat of the red alga *Gelidium pristoides*, upon which the limpet feeds. From a photograph by T. A. Stephenson.

T. A. Stephenson. *Neill & Co., Ltd.*

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXIV.

Death of His Majesty King George the Fifth

The accompanying message was sent by the Society:—

HIS EXCELLENCY THE GOVERNOR-GENERAL,
GOVERNMENT HOUSE,
CAPE TOWN.

The Royal Society of South Africa desire me to express our very deepest regret at the death of His Majesty, King George the Fifth.

We wish further that our strongest sympathies be made known to Her Majesty the Queen Mother and all the Royal Family, and to express our most loyal homage to His Majesty, King Edward the Eighth.

God save the King.

On behalf of the Royal Society of South Africa.

A. J. H. GOODWIN,
Honorary General Secretary.

CAPE TOWN, 23*rd January* 1936.

The following reply was received:—

GOVERNMENT HOUSE,
CAPE TOWN,
27th January 1936.

SIR,

With reference to your letter of the 23rd January, I am directed to inform you that the message of sympathy from the members of the Royal Society of South Africa on the death of His Majesty King George V was transmitted by cablegram through the usual channel for submission to Her Majesty The Queen and the Members of the Royal Family, and that I have received a reply from the Private Secretary, Buckingham Palace, London, desiring me to inform you that the message has been laid before Her Majesty and the Members of the Royal Family, who have commanded that an expression of their sincere thanks may be conveyed to the senders.

I am, SIR,

Your obedient Servant,

M. HORE-RUTHVEN.
Secretary to the Acting Governor-General.

THE HONORARY GENERAL SECRETARY,
ROYAL SOCIETY OF SOUTH AFRICA,
CAPE TOWN.

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXIV.

MINUTES OF PROCEEDINGS.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 20, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. ROGERS, was in the Chair.

Business:—

The Reports of the Honorary General Secretary and the Honorary Treasurer for the year 1934 were passed.

The following were elected Officers and Members of Council for 1935:—

President, A. W. ROGERS; Hon. Treasurer, L. CRAWFORD; Hon. General Secretary, A. J. H. GOODWIN; Hon. Editor of Transactions, R. S. ADAMSON; Hon. Librarian, E. NEWBERY; Council, K. H. BARNARD, J. W. BEWS, A. BROWN, J. P. DALTON, H. G. FOURCADE, J. JACKSON, C. VAN RIET LOWE, A. OGG, M. RINDL.

The President nominated A. BROWN and J. P. DALTON as Vice-Presidents for 1935.

Presidential Address, "The Solid Geology of the Kalahari."

ORDINARY MEETING.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

Minutes of the Meeting of Wednesday, October 17, 1934, were read and passed.

Dr. J. Jackson, M.A., D.Sc., was admitted a Fellow of the Society.

The following were proposed for Membership of the Society:—A. G. W. Compton, proposed by A. L. du Toit, seconded by Miss M. Wilman; Messrs. L. H. Wells and A. Galloway, proposed by R. A. Dart, seconded by M. R. Drennan; Messrs. O. S. H. Reinecke, M. S. du Toit, B. J. Dippenaar, C. J. Joubert, D. G. Haylett, proposed by C. W. Mally, seconded by P. A. van der Byl; D. W. Simpson, proposed by L. Crawford, seconded by A. Young; R. H. N. Smithers, proposed by E. Newbery, seconded by R. S. Adamson; M. H. Finlayson, proposed by J. W. Gunn, seconded by W. Campbell.

Communications:—

"Studies in Deciduous Fruit. II. The Effect of Time and Picking on Chemical Changes in Store of the Kelsey and Gaviota Plums," by I. Donen (communicated by J. Smeath Thomas).

"The Organic Matter Content and Carbon-nitrogen Ratio of South African Soils of the Winter Rainfall Area," by W. E. Isaac (communicated by R. S. Adamson).

A general account is given of the fractions of organic matter in the soil, and the effect of climatic conditions (temperature and humidity factors), soil character and depth on the organic matter content and on the C/N ratio is also dealt with. No previous investigation of this type has been carried out in South Africa.

Soil nitrogen was determined by the Kjeldahl method, soil organic carbon by the sulphur dioxide reduction method of Robinson, and organic matter by $C \times 1{\cdot}724$. The estimation of soil organic matter by the formula $N \times 20$ is shown to be entirely unsuitable for the soils investigated.

The C/N ratios of the soils studied range from 11·2: 1 to 22·9: 1, with an average for the twelve soils of 16·6: 1, and evidence is presented for regarding the C/N ratio of the winter rainfall region soils of the South-West Cape as being of the order of 15: 1. Within a rainfall locality the C/N ratio widens with increasing organic matter content.

In passing from soil to subsoil, with one exception (Krom River Farm), there is a marked decrease of organic carbon and nitrogen, and thus of organic matter, and this is accompanied by a narrowing of the C/N ratio. The organic matter content of Krom River Farm is practically the same for both soil and subsoil, and the C/N ratio shows a widening of 2·6 per cent. in the subsoil. The average C/N ratio of the six subsoils studied is 14·7: 1, or, excluding Kirstenbosch No. 1, 13·2: 1.

Analyses were made for soil at both a high (0–9″) and a low (27–36″) level in the case of Kirstenbosch No. 3. At the lower level the organic carbon was estimated as 1·25 per cent. lower and the C/N ratio 12·2 per cent. higher compared with the surface soil. On the whole the organic

matter content and the C/N ratio of the cultivated soils are lower than those of the virgin soils. Bredasdorp No. 1 is a remarkable virgin soil, having an organic matter content of 21·25 per cent., although this locality has the lowest rainfall of all the localities from which soil samples were collected.

"The Reproduction, Embryology, and Metamorphosis of the Cape Crawfish, ***Jasus lalandii***," by C. von Bonde.

Heretofore no serious attempt has been made to study the reproductive and embryological processes of the Cape Crawfish. In the present paper these functions are dealt with, and the physiology and morphology of the reproductive systems in the sexes of Crawfish are worked out in detail. The question of frequency of spawning and the number of eggs produced is examined.

The embryology is worked out in detail for the first time, and all the stages from the time of the extrusion of the eggs and their attachment to the pleopods of the female's abdomen worked out. The nauplius stage which is here passed in the egg is determined as appearing 35 days after the eggs are laid. A new stage in the larval development, the "Pre-naupliosoma" is described as this stage, was actually observed immediately the eggshells burst. The various stages in the subsequent metamorphosis are described, the experiments having been conducted in a specially constructed hatching box. An attempt is made to determine the rate of growth of the Crawfish from the time the first true crawfish form was observed up to the time of sexual maturity.

A. J. H. Goodwin,
Hon. General Secretary.

Report of the Hon. General Secretary for 1934.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "A New Variation of Smithfield Culture from a Cave on the Pondoland Coast," by E. C. Chubb, G. Burnham King, and A. C. D. Mogg (communicated by C. van Riet Lowe).
2. "The Stratification of the Superficial Deposits at Mossel Bay and the Age of the Mossel Bay and other Lithic Industries," by T. F. Dreyer.
3. "An Anatomical Study of the Roots of Grasses," by A. P. Goossens.
4. "Neolithic Stone Implements found at Regina in the Western Transvaal," by Margaret Orford (communicated by R. A. Dart).
5. "Bird Population Studies, V. An Analysis of the Avifauna of the Jeans School Station, Mazabuka, Northern Rhodesia," by J. M. Winterbottom.

6. "Water Absorption by Leaves of Crassula," by M. A. Keay (communicated by R. S. Adamson).

7. "The Archaeology of the Prehistoric Settlements in the Heilbron Area," by P. W. Laidler (communicated by R. A. Dart).

8. "Researches on Chlorosis in Deciduous Fruit Trees," by W. E. Isaac (communicated by R. S. Adamson).

9. "Smithfield Implements from a Natal Coast Site," by J. Gordon Cramb (communicated by R. A. Dart).

10. "Report on Human Skeletal Remains from Karridene Site," by A. Galloway and L. H. Wells (communicated by R. A. Dart).

11. "A Further Note on Human Skeletal Remains from the Natal Coast," by L. H. Wells (communicated by R. A. Dart).

12. "The South African Species of the Triglid Genera: *Lepidotrigla* and *Peristedion*," by J. L. B. Smith.

13. "Diurnal and Secular Variations of the Earth's Magnetic Field at Cape Town," by A. Ogg, E. N. Grindley, and B. Gotsman.

14. "The Vegetation and Flora of Robben Island," by R. S. Adamson.

15. "Studies in Deciduous Fruit: the Effect of Time of Picking on the Keeping Quality of Plums—with especial reference to the Internal Browning of the Kelsey Plum," by I. Donen.

16. "The South African Literary and Scientific Institution, 1833–1857," by L. Crawford.

17. "Contributions to our Knowledge of the Freshwater Algae of Africa. No. II. Algae from a Pan in Southern Rhodesia," by Florence Rich (communicated by Miss E. L. Stephens).

18. "On a Corosion Problem," by E. Newbery.

19. "New South African Solifugae," by R. F. Lawrence.

20. "The Influence of Testicular and of Urinary Extracts on the Creatinine Excretion in Rabbits," by R. W. S. Cheetham, I. Schrire, and H. Zwarenstein.

21. "The Effect of Hypophysectomy and Crastration on Muscle Creatine in *Xenopus Laevis*," by B. G. Shapiro and H. Zwarenstein.

22. "The Bio-Assay of the Gonadokinetic Principle of the Anterior Pituitary," by S. Honikman, H. A. Shapiro, and H. Zwarenstein.

23. "Vesalius on China-Root," translated from the Latin by Benjamin Farrington.

24. "Notes on Nomenclature of South African Compositae," by M. R. Levyns.

25. "A New Lamellibranch from the Upper Dwyka Beds of South-West Africa," By F. R. C. Reed (communicated by S. H. Haughton).

26. "Variations in the Ovarian Response of Xenopus to the Gonadokinetic Principle of the Anterior Pituitary, I," by S. Honikman, H. A. Shapiro, and H. Zwarenstein.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1934.

Revenue.

		£ s. d.	£ s. d.
To Subscriptions collected for 1934:—			
Subscriptions collected for 1931		2 0 0	
,, ,, 1932		5 0 0	
,, ,, 1933		28 0 0	
,, ,, 1934		252 15 7	
,, ,, in advance for 1935		3 2 0	
,, ,, in advance for 1934		3 7 8	
,, ,, for 1915, 1916, 1917, previously written off		3 0 0	
Outstanding Subscriptions at December 31, 1934		64 14 4	
		361 19 7	
Less: Outstanding Subscriptions at December 31, 1933, £65; Subscriptions for 1933 held by Neill & Co., £2; Subscriptions collected in 1934 for 1935, £3 2s.		70 2 0	
			291 17 7
,, Entrance Fees			5 0 0
,, Government Grant			400 0 0
,, Interest received:—			
On money in Savings Bank Department of Standard Bank		4 18 11	
On money in Cape of Good Hope Savings Bank		12 1 7	
			17 0 6
,, Sale of Publications in 1934		55 16 1	
Plus: Amount due for Sales in 1934 ..		5 10 0	
Amount paid to Neill & Co. for sale and held by them		0 13 6	
		61 19 7	
Less: Amount paid to Neill & Co. for Sales in 1933 and held by them till 1934 ..	£3 5 9		
Neill & Co. Sales Account, 1933 ..	3 10 10		
1932 Account paid in 1934	1 15 6		
Sum paid in advance by Stechert & Co. for Transactions	0 15 4		
		9 7 5	
			52 12 2
,, Sale of Covers for Binding			1 11 4
,, Loss in Year 1934			136 2 6
			£904 4 1

Expenditure.

	£ s. d.	£ s. d.	£ s. d.
By Publications:—			
Chiswick Press for Plates in Vol. XXI., Part 3	23 0 0		
Loss on Exchange and Cost of Draft	0 5 1		
Neill & Co. for Vol XXI.—			
Part 3	87 2 0		
Part 4	152 8 9		
Vol. XXII.—			
Part 1	134 8 2		
Part 2	100 19 3		
Part 3	113 6 11		
Cost of Draft to Neill & Co. ..	4 19 9		
Plus: Amount due for Vol. XXII., Part 4	161 15 3		
Balance of Neill & Co.'s Account	2 6 9		
		780 11 11	
Less: Amount due for Vol. XXI., Part 3, issued December, 1933 ..	110 2 0		
Grant from Research Grant Board ..	60 0 0		
Refund on Vol. XXI., Part 3	1 16 6		
Receipts from Sales of Extra Reprints ..	10 17 9		
Amount due for Sale in 1934	0 15 0		
		183 11 3	
			597 0 8
,, Compilation of International Catalogue of Scientific Literature			16 16 0
,, Clerical Assistance and Work in Library			102 6 0
,, Local Printing and Stationery			41 10 0
,, Postages and Petties			13 8 3
,, Bank Charges for Commissions, Ledger Fees, etc.		£3 17 3	
Less: Commissions paid by Members ..		1 16 6	
			2 0 9
,, Hire of Rooms and Caretaker			6 6 0
,, Insurance of Library and Insurance of back numbers with Neill & Co.			1 16 3
,, Binding			112 18 6
,, Purchases		£10 9 8	
Less: 1933 Account paid in 1934		0 8 0	
			10 1 8
			£904 4 1

ASSETS AND LIABILITIES AT DECEMBER 31, 1934.

Assets.*	£ s. d.
Money in Savings Bank Department of Standard Bank ..	19 3 8
Money in Cape of Good Hope Savings Bank	314 1 7
Money in Post Office Savings Bank	150 0 0
Balance at Standard Bank as per Pass Book	33 10 7
Arrears of Subscriptions as in Statement for 1933, £65; less £33 paid in 1934 and £12 struck off as irrecoverable	20 0 0
Arrears of Subscriptions for 1934, £50 14s. 4d.; less £6 struck off as irrecoverable	44 14 4
Amount due for Sale of Publications in 1933	1 0 11
Amount due for Sale of Publications in 1934	5 10 0
Amount due for Sale of Extra Reprints in 1931	1 5 9
Amount due for Sale of Extra Reprints in 1934	0 15 0
	£590 1 10

Liabilities.	£ s. d.	£ s. d.
Subscriptions received in advance for 1935 ..		3 2 0
Amount for Sale of Publications received in advance in 1934		0 15 4
Amount for Sale of Publications received in advance in 1931		0 18 9
Amount owing to Neill & Co. for Vol. XXII., Part 4, issued December 1934	161 15 3	
Amount owing Neill & Co. for balance of Account	2 6 9	
	164 2 0	
Less: Amount held by Neill & Co. for Sale of Publication	0 13 6	163 8 6
Excess of Assets over Liabilities:— Amount put down at December 31, 1933	558 18 6	
Less Liability for amount for Sale of Publications received in advance in 1931, not reckoned in last accounts	0 18 9	
	557 19 9	
Less: Loss in 1934	136 2 6	421 17 3
		£590 1 10

* Exclusive of value of Library and Publications of the Society held in stock.

LAWRENCE CRAWFORD,
Hon. Treasurer.

We hereby certify that we have examined the above Accounts of Revenue and Expenditure, and of Assets and Liabilities, with the books, vouchers, and other documents relating thereto, and that in our opinion these Accounts set forth a correct statement of the affairs of the Society.

B. J. RYRIE.
J. W. C. GUNN.

February 12, 1935.

The following exhibitions have been held:—

1. "Abnormal Dentition of a Bushman Skull," by A. J. H. Goodwin.

2. "Peninsula Clays and their Economic Values," by H. Jacobs (communicated by J. Smeath Thomas).

3. "Some Peculiar Fish Scales," by K. H. Barnard.

4. "Whorls in a Lamp-Glass," by E. L. Gill.

5. "Some Desert-Living Animals," by R. F. Lawrence.

6. "Some Oceanographic Results of the 'Discovery' Survey," by K. H. Barnard and W. J. Copenhagen.

7. "Some Rainmaking and Divining Methods of the Bakxatla," by I. Schapera.

8. "A Proposed Method for the Quantitative Estimation of Phytoplankton," by W. J. Copenhagen.

Vol. XXI, part 4, and Vol. XXII, parts 1 to 4, of the Society's Transactions have been issued during the year.

John Jackson, Adrianus Pijper, William Pugh, Isaac Schapera, and Thomas Alan Stephenson were elected Fellows of the Society in 1934.

At the end of 1934 the number of Honorary Fellows was 1, Fellows 78, Members 123. During the year one Fellow and five Members resigned as from the end of 1934, and the name of one Fellow and three Members were struck off the list. Five new Members were elected.

The death in 1934 of Sir Thomas Muir (a Foundation Fellow) is recorded with regret. An obituary notice was published in Vol. XXII., part 1, 1934, of the Society's Transactions.

The thanks of the Council are due to the Minister for Education and the Government for the grant of £400 for the year 1934–5; the Council's thanks are due, too, to the Research Grant Board for a grant of £60 towards printing papers by K. H. Barnard and C. von Bonde.

A catalogue of the Society's Library has been prepared. This is now in the press and will be issued during the coming year. The thanks of the Society are due to the Librarian and staff of the Library of the University of Cape Town for undertaking the arduous work of preparing this catalogue and of seeing it through the press.

The following gifts were received by the Library during the year:—

From Biblioteca Nacional, Buenos Ayres, Regimen Fiscal de Seguros, 2 vols., by Pedemonte; from Italian Legation, Cape Town, Colombo; from Messrs. Wm. Clowes & Sons, Beccles, Map and plates illustrating Ruwenzori Expeditions of Dr. Noel Humphreys, 1932; from Research Grant Board of South Africa, The Rock-engravings of Griqualand West and Bechuanaland, by M. Wilman; from the Abbé Breuil, Les Peintures Rupestres Schématiques de la Peninsule Ibérique, part 3, by the Donor.

The Society is at present receiving some 416 scientific journals in exchange for the Transactions.

In future arrangements have been made for the submission of abstracts of all biological papers in "Biological Abstracts."

Existing exchanges have been maintained, and the following new exchanges have been arranged during the year:—Musée Royal d'Historie Naturelle de Belgique, Bruxelles; Indian Botanical Society, Madras.

The University Librarian reports that the Library is being increasingly used by students.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 17, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. ROGERS, was in the Chair.

Business:—

The Minutes of the Meeting of March 20, 1935, were confirmed.

On the motion of A. BROWN it was agreed to print the précis of the paper by I. DONEN read at the March meeting. As the Secretary has been unable to obtain the précis in time, this will be printed in the Minutes of the Meeting to be held on May 15.

The following were elected to Membership of the Society:—A. G. W. COMPTON; L. H. WELLS; A. GALLOWAY; O. S. H. REINECKE; M. S. DU TOIT; B. J. DIPPENAAR; C. J. JOUBERT; D. G. HAYLETT; D. W. SIMPSON; R. H. N. SMITHERS; M. H. FINLAYSON.

The following were nominated to Membership of the Society:—D. J. MALAN and D. B. HODGES, proposed by B. F. J. SCHONLAND, seconded by A. OGG; M. H. GIFFEN, proposed by R. S. ADAMSON, seconded by M. R. LEVYNS; W. S. S. Ladell, proposed by H. ZWARENSTEIN, seconded by I. SCHRIRE.

Communication:—

"Veld-burning Experiments at Oakdale, Riversdale," by M. R. LEVYNS.

These experiments have extended over five years and have been carried out on rhenosterveld.

The results after burning differ from those previously obtained at Stellenbosch. There an immediate return to rhenosterveld was demonstrated. In this case the vegetation undergoes a series of successional changes before rhenosterveld is once more established.

The results of clearing are similar to those obtained at Stellenbosch.

An attempt is made to correlate the differences between the two localities in their response to burning with climatic differences.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 15, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

The Minutes of the Meeting of Wednesday, April 17, 1935, were confirmed.

The following were elected to Membership of the Society:—D. J. Malan and D. B. Hodges, proposed by B. F. J. Schonland, seconded by A. Ogg; M. H. Giffen, proposed by R. S. Adamson, seconded by M. R. Levyns; W. S. S. Ladell, proposed by H. Zwarenstein, seconded by I. Schrire.

The President announced the following candidates for Fellowship:—George Arnold, proposed by J. Hewitt, E. L. Stephens, J. H. Power, I. Schapera; Reginald Frederick Lawrence, proposed by T. A. Stephenson, J. Hewitt, J. H. Power, C. F. Juritz; Cecil von Bonde, proposed by T. A. Stephenson, J. Hewitt, J. H. Power, C. F. Juritz.

Communications:—

"Notes on a Second Intermediary Host for Trematodes," by F. G. Cawston.

"On the Flora of a High Mountain in South-West Africa," by J. V. L. Rennie.

Evidence is given that in the higher parts of the Auas Range, near Windhoek, the thornveld is replaced by small shrubs, several of which might be interpreted as relics of an older flora in South-West Africa. *Passerina* and *Stoebe plumosa* are recorded for the first time from that territory. It has generally been assumed, owing to the absence of records of the more typical members of the Cape Flora from the mountains of South-West Africa, that the presence of certain Cape genera in East Africa and Angola is due to migration in former times *via* the eastern side of the subcontinent. The species here recorded come from a locality in the west just half-way between the south-western region and Angola, and the occurrence indicates that at least certain elements of the Cape Flora could have reached the Huilla Plateau in Angola *via* a western route.

"Some Prehistoric Skeletal Remains from the Natal Coast," by A. GALLOWAY.

"The 'Galjoen' Fishes of South Africa," by J. L. B. SMITH.

The Galjoen fishes are placed in a genus of somewhat doubtful taxonomic position. Owing to a combination of characters the institution of a new family (*Dichistiidae*) is proposed. To the two known species, a new species is added; and figures of all three species are given. The anatomy, generic and specific characters, and the biology are discussed.

"Some Biological Notes on *Boscia rehmanniana*, Pest., and *Olea verrucosa*, Link," by E. E. GALPIN and E. A. GALPIN.

"The Organic Matter Content and Carbon-Nitrogen Ratios of Some Semi-Arid Soils of the Cape Province," by W. E. ISAAC and B. GERSHILL, (communicated by R. S. ADAMSON).

The organic matter content and C: N ratios of some semi-arid soils of the Cape Province are discussed. The average C: N ratio for these, namely, 10.6: 1, is contrasted with that of the winter rainfall area (15: 1). Decreasing organic matter content is shown to be accompanied by a decreasing C: N ratio. Although the organic matter of the semi-arid type of soil is low, the percentage of nitrogen in the organic matter itself was found to be higher than for the winter rainfall series. Hydrogen-ion concentration figures are given, which show the semi-arid type of soil to be the more alkaline of the two.

"The Effect of Time of Picking on the Chemical Changes of Kelsey and Gaviota Plums in Store," by I. DONEN (paper communicated by J. SMEATH THOMAS; read at the Ordinary Meeting of the Society held on March 20, 1935).

The effect of time of gathering on the changes, in acid, H-ion concentration, and sugar content of the two varieties of plums during subsequent storage at 34–36° F., have been investigated. Four pickings of each variety of plum were made, and the course of chemical change was followed by means of weekly analyses. Results have been expressed on the basis of unit total nitrogen.

It was found that time of picking had no marked effect on chemical changes in the Gaviota plums. First appearance of bladderiness in all samples was noticed after about 44 days in store. Coincident with this breakdown a complete reversal of the sugar equilibrium was observed in the last two pickings.

Marked differences were observed between the changes of the constituents of the early and late pickings of the Kelsey plums. In the first two pickings rate of loss of sugar was initially high and then declined rapidly to a minimum. The rate of sugar loss in the last two pickings remained uniform throughout the observed storage life.

Internal browning of the tissue occurred sooner in the early pickings than in the later ones. Simultaneously with the onset of browning in the Kelsey plums a reversal of sugar equilibrium was noticed. This reversal was rapid in the first two pickings but slow in the last two.

It was found that acid loss was high when sugar consumption was low, and it is suggested that increase in rate of loss of acid is not a concomitant of internal breakdown, but rather an "overdraft" on stored acid due to insufficient supply of acid from oxidation of sugars.

It is indicated that acid loss is regulated by both acid concentration and nitrogen content. Low nitrogen and low acid therefore favour good keeping quality. This is correlated with delay in time of picking.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 19, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

The Minutes of the Meeting of Wednesday, May 15, 1935, were confirmed.

Communications:—

"The Alkaloids of Strychnos Henningsii (3rd Communication) Isolation of a Second Crystalline Alkaloid," by M. Rindl and M. L. Sapiro.

On the basis of a large number of analyses of the crystalline alkaloid isolated both by the authors and by the firm of E. Merck, of Darmstadt, Germany, the formula $C_{22}H_{25}N_2O_4(OCH_3)$ is ascribed to this compound. This formula differs from the one previously suggested. The alkaloid is probably phenolic, but attempts to methylate it with diazomethane for the purpose of ascertaining the number of hydroxyl groups proved abortive. Methylimido groups are absent. The crude alkaloid is accompanied by very small quantities of a second alkaloid which can be removed by continuous percolation with ether and purified by high vacuum sublimation (0·03 mm. 190–200 C). Analyses suggest the formula $C_{22}H_{24}N_2O_3(OCH_3)_2$. Melting-point 214·5–215 (corrected). Molecular weight by micro methods 446 and 412. Calculated for above formula 426. The above formula differs from that of the first crystalline alkaloid by an increment of CH_2. The likelihood is that the two alkaloids are the monomethoxy and dimethoxy

derivatives of the same mother substance. With Froehde's reagent the new alkaloid gives colour reaction similar to that of the two colubrines, alkaloids which have recently been isolated from the mother liquors of the strychnine industry. There is also evidence of the presence of a third crystalline alkaloid.

"The Genus *Tripterodon*, Playfair," by J. L. B. Smith.

The fish *Tripterodon*, whose anatomy and taxonomic features have hitherto been inadequately studied, is here investigated. Morphologically it appears that it should be included in the family *Platacidae*. The characters of this family and its component genera are described, together with those of the single South African representative. Figures of the external appearance and skeletal structures are given.

"*Taraxacum magellanicum* Comm. in South Africa," by J. Burtt Davy.

"The Nature of Temperament," by S. Biesheuvel (communicated by H. A. Reyburn).

The behaviour qualities grouped together under the heading of Temperament have been reduced to three distinct units, for each of which a psychological explanation has been found. The relationship of these fundamental factors to environmental influences and organic processes has been tentatively determined.

"Note on the Stem Structure of *Boscia rehmanniana*, Pest.," by R. S. Adamson.

The old stems have anomalous secondary thickening with successive extrafascicular cambia. These arise as separate portions and develop tissues both centrifugally and centripetally. The centrifugal growth is much greater than the centripetal.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 17, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

The Minutes of the Meeting of Wednesday, June 19, 1935, were confirmed.

Communication:—

"Recent Changes in Terminology in European Prehistory," by A. J. H. Goodwin.

The term Clacton has been introduced in Europe to cover a flake culture which is found to divide the Chellean and Acheulean.

When Gabriel de Mortillet first organised the prehistoric period of France into a single chronological scheme, the site at Le Moustier shelter was made the type site of a major period. Later work by Commont on the gravels of the Somme River necessitated the introduction of the term Levallois to cover part of the complex present at Le Moustier. Recent work by Dr. Ami at Combe Capelle, and by Henri Martin at La Quina have rendered a further analysis necessary. As a result the Le Moustier site is now regarded as presenting three cultural themes, which here mingle. The Levallois, the true Moustierian, and the Acheulean tradition.

Subsequently Péyrony, Breuil, and others have shown these themes in their earlier forms, and terms have been applied to cover these developments.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 21, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Prof. A. Brown, was in the Chair.

Business:—

The Minutes of the Meeting of Wednesday, July 17, 1935, were confirmed.

The Chairman announced that the Annual Meeting for the Election of Fellows would take place on Wednesday, September 18, 1935.

Communications:—

"Observations on certain Wood-boring Coleoptera occurring in South Africa," by J. A. Pringle (communicated by J. F. V. Phillips).

"The Smithfield 'N' Culture," by C. van Riet Lowe.

Attention is drawn to the wide range of artifacts employed by those who practised this variation of the main Smithfield Culture. Sites and assemblages of artifacts are described and it is suggested that this peculiar variation of the parent culture owes its characteristics to a changed environment—necessitating a change in employments and in consequence a new variety of tools —brought about by a migration and probably influenced by other cultures.

A description, illustrated by a map, is given of the diffusion of the Culture and the five marked, yet intimately related variations of the common parent are linked up and explained.

Exhibition:—

"Seismographic Records of the Quetta Earthquake, as received at Cape Town," by A. Brown.

A model of the Milne-Shaw Seismograph was exhibited, also maps and diagrams used in preparing bulletins.

Among the earthquake records shown were the following:—

Grahamstown: August 9, 1932.
Bihar: January 15, 1934.
Quetta: May 30–31, 1935.
Kenya: May 14–15, 1935.

A. J. H. Goodwin,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society was held on Wednesday, September 18, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

Election of Fellows: The following were elected to Fellowship:— George Arnold; Reginald Frederick Lawrence; Cecil von Bonde.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of August 21, 1935, were confirmed.

Communications:—

"Studies in Deciduous Fruit III: The Chemical Changes in Kelsey and Gaviota Plums during Growth," by I. Donen.

The life of the Kelsey and Gaviota plum on the tree may be divided into three stages. During the first stage the growth of the stone predominates over that of the flesh. The rate of growth, and of increase of all constituents of the flesh, except alcohol insoluble residue, is comparatively slow. The concentration of total solids, alcohol insoluble residue and nitrogen falls rapidly during this period, but acid concentration remains high. Starch is present in the plum at the beginning of this stage only and for but a short period.

The second stage of growth commences when the stone is fully developed. It is characterised by a rapid rise in the rate of growth of the plum and in the rate of increase of total solids, sucrose, nitrogen, and acid per fruit. These rates of increase finally reach a maximum value at the end of this stage.

The third stage of growth is a period of maturation. The rate of accumulation of constituents per plum falls rapidly. The fruit softens, acquires colour and finally becomes fully ripe. It was observed that

sucrose and nitrogen accumulate in the flesh as long as the plum remains on the tree.

It is suggested that organic acids and alcohol insoluble residue have a common origin. Starch appears to be formed alternatively to acids. Nitrogen intake was found to be related to growth. A high rate of growth is accompanied by a high rate of acid formation. It is indicated that the metabolic changes in the plum during growth are reflected in the changes of the sugar fractions.

The rate of increase of constituents in the plum was higher in the 1934–35 season than in the 1933–34 season. This is ascribed to the poorer crops borne by the plum trees in 1934–35. It was found that the composition of the plums was affected more by seasonable variations than by differences in environment.

"Studies on Dropping-Berry in Waltham Cross Grapes (*Vitis vinifera*)," by D. G. Haylett.

"Some Interesting New Fishes from South Africa," by J. L. B. Smith.

Two noteworthy additions, one of a genus, the other of a family, new to the South African marine ichthyfauna list are described and figured. *Scymnus brevipinnis* n.sp. is a shark from deep water off Algoa Bay. Species of this genus have hitherto been recorded only from the North Atlantic and from Japan. *Taeniolabrus marleyi* n.sp., recently obtained at Durban, is a member of the little-known family. *Trichonotidae*, hitherto recorded only from the Indo-Australian region.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 16, 1935, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. A. W. Rogers, was in the Chair.

Business:—

The Minutes of the Meeting of Wednesday, September 18, 1935, were confirmed.

Council:—

The Council recommended the following for election to the Council for 1936:—

President, L. Crawford; Hon. Treasurer, A. Brown; Hon. General Secretary, A J. H. Goodwin; Hon. Editor of Transactions, R. S. Adamson; Hon. Librarian, E. Newbery; Council, K. H. Barnard, H. G. Fourcade, J. Jackson, R. F. Lawrence, E. P. Phillips, A. W. Rogers, B. F. J. Schonland, H. Stephen, R. B. Young.

Nominations:—

The following were nominated for election to Membership of the Society: —W. S. RAPSON, proposed by E. NEWBERY, seconded by J. SMEATH THOMAS; I. DONEN, proposed by E. NEWBERY, seconded by J. SMEATH THOMAS.

Communications:—

"Variation in the Phytoplankton of Table Bay, October 1934–October 1935, with a Note on the Chemical Analysis of *Chaetoceras*," by W. J. COPENHAGEN.

Using the apparatus demonstrated to the members of the Royal Society, October 17, 1934, quantitative catches have been made approximately every fortnight during the above period. Qualitative catches were also undertaken during these runs with ½-metre diameter 200 mesh nets. The quantitative catch was estimated in terms of "Colour Units" (plant pigments), Harvey's method.

A graph was exhibited showing "Colour Units," Surface Temperature, and hours of actual sunshine.

A list of the dominant species of phytoplankton was appended and comparative counts were made. It would appear that *Chaetoceras* was dominant on over 70 per cent. of the occasions that catches were obtained during the above period.

A chemical analysis and also the Calorific Value of a catch consisting of 90 per cent. of *Chaetoceras* is included.

A suggestion is tentatively made that the available energy of a cubic metre of sea water be expressed in terms of calories.

"The Relation between Thunderstorms and Atmospherics in South Africa," by D. B. HODGES and B. F. J. SCHONLAND.

A short description was given of the Cathode Ray Direction Finder, as installed at the University of Cape Town. The results obtained with the instrument during part of September and October, 1935, have been compared with meteorological maps for the same period, kindly supplied by the Chief Meteorologist, Irrigation Department, Pretoria, and by the Chief Meteorologist of Southern Rhodesia.

The results show close agreement between the bearings of thunderstorms within a distance of about 1000 miles as recorded on the maps and directions of arrival of signals at the apparatus at corresponding times. Variations in the amplitude of atmospherics with distance, and with time of day or night, have been studied. The results also show occasionally the existence of sources not recorded on the maps, some over the sea and some (probably due to an incomplete report system) over land. A satisfactory correlation of atmospherics from sources over the sea with depres-

sions in the same areas has been made, particularly in the case of depressions off the South-West coast.

The very active region with its centre approximately lat. 10° S. long. 20° E., noticed by Munro and Huxley in Australia, comes into action at Cape Town about 15 hours local time, and continues throughout the afternoon and early part of the night.

The experiments indicate the value of this device both for meteorological forecasting and for information on disturbed weather areas for aircraft.

"Recent Progress in the Study of the Lightning Discharge," by B. F. J. SCHONLAND, D. J. MALAN, and H. COLLENS.

Investigations under the auspices of the South African Institute of Electrical Engineers have permitted of a general description of the nature of the discharge between cloud and ground. The leader-return stroke sequence is present in practically every case.

The effective velocity of the stepped leader is that to be expected from electron-avalanche drift in the critical field for breakdown (2×10^7 cms./sec.). It is suggested that an actual pilot streamer travelling with this effective velocity but carrying too small a current to be photographed provides the necessary ionisation for the luminous heavy-current step which follows it with a velocity of about 5×10^9 cms./sec. The latter proceeds according to the mechanism suggested by Cravath and Loeb (*Physics*, 6, p. 125, 1935), and catches up the pilot streamer. The absence of further ionisation ahead of the step then causes a pause in which the high conductivity leader streamer is reorganised and during which the pilot forges ahead.

The existence of the stepped and the dart-stepped leader indicates that a considerable degree of ionisation must exist before the Cravath-Loeb process is effective and that these authors are in error in supposing that ordinary atmospheric ionisation is sufficient. Electron-capture, which has not been considered by Cravath and Loeb, would explain this insufficiency.

"Intensity Variations in the Main Return Lightning Stroke," by D. J. MALAN.

The variation in intensity in return lightning strokes was determined by examining photographs obtained with a Boys camera. The densities of the photographic images of lightning flashes were determined by means of a recording microphotometer.

The main stroke intensity fluctuates in such a manner as to cause the return channel luminosity to be divisible into a series of component discharges, all apparently passing upwards from the ground.

A maximum of six such component discharges comprising a complete return stroke has been observed.

The following table gives the time interval between the first appearance of luminosity in the return channel and the start of the subsequent components:—

Component.	Time Interval (microseconds).
1	0.
2	7·4 to 75.
3	37 to 370.
4	110 to 580.
5	510 to 2100.
6	815 (only one case).

Component 2 is of the same order of intensity as component 1. If this intensity is taken as unity, the intensity of component 3 is of the order of 1/10 and that of component 4 is of the order of 1/200. The subsequent components, where seen, were too weak for a satisfactory determination of their intensities to be obtained.

There is evidence to show that the second and sometimes the third component is related to the existence of the charge distributed along the leader branches. Where prominent branches do not exist the second component does not start before the first has reached the cloud.

"Several new Gobioid and Fresh-water Fishes from South Africa," by J. L. B. Smith.

Five new species are described and figured: *Gobius vonbondei* from Natal; *Gobius gulosus* from the Bushman's River, Alicedale, in the Eastern Province of South Africa—the first record of a Gobioid fish from so far inland in that part of South Africa; *Eleotris limosus* taken in the Isipingo Lagoon; *Barbus senticeps* from the Kromme River, Assegaibosch, near Humansdorp, an addition to the scanty fresh-water ichthyfauna list of the Eastern Province; *Chiloglanis natalensis* from Paulpietersburg, Natal, is the first record of a species of this north and central African genus from South Africa.

"Studies in South African Ricciaceae.—I. Three Annual Species: *R. crystallina*, L., *R. cupulifera* sp. nov., and *R. curtisii* T. P. James," by A. V. Duthie and S. Garside.

This paper is the first of a proposed series dealing with South African Ricciaceae. It includes a discussion of the taxonomic history of the family, and a detailed account of three annual species which are common in the Cape and Stellenbosch Divisions, but have hitherto been confused. One of the above, *R. crystallina*, is cosmopolitan, another, *R. curtisii*, is fairly abundant in parts of America, but has not previously been known to occur in South Africa, while the third, *R. cupulifera*, is here described as new.

A. J. H. Goodwin,
Hon. General Secretary.